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James Hutton's Medical Dissertation

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JAMES HUTTON'S MEDICAL DISSERTATION

ARTHUR DONOVAN AND JOSEPH PRENTISS

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INTRODUCTION

The following introduction seeks to make Hutton's dissertation more accessible by analyzing its contents and setting it into its historical context. Part I contains brief historiographic and biographical sketches of the author. Part II is an exposition of the conceptual structure of the dissertation. Part III attempts to identify and describe the sources of the doctrines that inform the dissertation. What is not attempted, and now emerges as the next scholarly task, is a study of the relations between the ideas contained in the dissertation and those presented in the various works Hutton published in the final years of his life.

PART I—TRANSLATOR'S PREFACE

A. The Hutton of History

The theory of the earth James Hutton presented to the Royal Society of Edinburgh in 1785, and then published in the first volume of that Society's *Transactions* and in a later two-volume work, has long been considered one of the great achievements of modern geology's heroic age.[1] Evidence of this judgment comes easily to hand. Archibald Geike, for instance, in his pioneering *The Founders of Geology*, titled the chapter on Hutton's contribution "The Rise of the modern conception of the theory of the Earth," while the Hutton memorial tablet unveiled in Edinburgh's Greyfriars Churchyard in 1947, the 150th anniversary of his death, identifies him quite simply as "the Founder of Modern Geology."[2] Such claims may be excessive, but they do indicate the high regard in which historically informed geologists hold Hutton's achievement.

Hutton's theory has been characterized in various ways. For Victor Eyles, "the most important advance in geological science embodied in Hutton's theory was his demonstration that the process of sedimentation is cyclical in operation, a principle now accepted as axiomatic."[3] Hutton argued that sediments formed by erosion are carried to the bottom of the oceans, where the central heat of the earth acts first to consolidate them and then to elevate the newly formed strata into mountain ranges. This emphasis on cyclicity, when coupled with Hutton's insistence that the landforms we see about us were molded by forces acting in the world today, was itself elevated in the early decades of the nineteenth century into the principle of uniformitarianism, a principle Charles Lyell made central to his influential geological theory. Since Lyell's time geologists have abandoned their former belief in absolute cyclicity, a shift paralleled by a growing awareness that Hutton was not nearly as dogmatic as Lyell on this point. Indeed, according to R. H. Dott, the dynamic aspects of Hutton's theory deserve more emphasis than the cyclic aspects: "Hutton perceived what we today may term *dynamic equilibrium*, and the concept is of enormous importance in natural science."[4] Thus despite fundamental changes in the earth sciences, Hutton's theory of the earth has through reinterpretation endured as a landmark in the history of geology.

Hutton has also recently attracted increased attention from historians of eighteenth-century natural philosophy. Patsy Gerstner and Robert Schofield see Hutton as a neo-mechanist reviving a force theory of matter favored by Newtonian scientists in the first half of the eighteenth century, one which had been displaced by materialist concepts of active principles from about 1740 on. This view then leads them to conclude that "Hutton's major accomplishment . . . was the application of this theory of matter to geology."[5] According to P. M. Heimann and J. E. McGuire, Hutton's theory of matter was less a revival of earlier mechanistic ideas than the culmination of a distinct and in many ways anti-Newtonian theory of active matter: "In rejecting Newton's doctrine of essential qualities, eighteenth-century thinkers such as James Hutton were to reject Newton's view that the invisible primordials had properties in common with those of sensible bodies. . . . Hutton, therefore, transformed Newton's theory of forces . . . into a conception of nature as a self-contained, active system, which in its structure manifested the wisdom and design of God." This theory of active matter, in combination with Hutton's deistic belief that nature embodies the perfection of God, is then presented as the source of Hutton's geological theory.

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[1] James Hutton, "Theory of the Earth; or an Investigation of the Laws Observable in the Composition, Dissolution, and Restoration of Land Upon the Globe," *Transactions of the Royal Society of Edinburgh* 1 (1788): pp. 209–304, and *Theory of the Earth: With Proofs and Illustrations,* (2 v., Edinburgh, 1795).

[2] Archibald Geike, *The Founders of Geology,* 2nd ed. (New York, 1905), ch. IX. "James Hutton 1726–1797, Commemoration of the 150th Anniversary of His Death," in *Proceedings of the Royal Society of Edinburgh* **63B** (1950): pp. 351–402, Preface and Plate I.

[3] Victor Eyles, "James Hutton," *Dictionary of Scientific Biography* 6 (New York, 1972): pp. 577–589, p. 582.

[4] R. H. Dott, Jr., "James Hutton and the Concept of a Dynamic Earth," in C. J. Schneer, ed., *Toward a History of Geology* (Cambridge, Mass., 1969), pp. 122–141, p. 140.

> Thus [for Hutton] nature was a system of organic processes, manifesting cycles among cycles arising from the resultant tension of repulsive and attractive power producing a state of equilibrium. These are the fundamental principles constitutive of Hutton's system. And his view of uniformitarianism and the doctrine of economy of geological forces are, for Hutton, closely linked to these principles.[6]

Other recent commentators have traced Hutton's geological ideas back to different sources. J. E. O'Rourke has argued that what is significant in Hutton's theory flows directly from the novel view of science he brought to his geological investigations. "What was new in Hutton's theory came from the use of a recently developed empirical philosophy based on the premise that all knowledge begins with experience. What was omitted from the theory was judged by a new critical or pragmatic philosophy, worked out by Hutton himself, that also makes experience the criterion of knowledge."[7] Roy Porter has taken a more contextual approach in arguing that "Hutton's philosophy of the Earth was unique in its day, and arose from a unique milieu. This milieu was doubly special, in being Scottish, yet also distinct from the milieu of Scottish *geology*." For Porter, "the milieux of Hutton's career were those of Enlightenment Paris, Leiden, and then, for most of his later life, Edinburgh. And above all, his intellectual context was *not that of Earth Science*, but rather that of the synthetic philosophical ambitions of the Scottish Enlightenment. . . . Hutton's ideas played an equivalent role in Scottish geology to that of [David] Hume's and [Adam] Smith's writings in their own respective fields."[8] This approach to an understanding of Hutton's theory of the earth, so unlike the empirical and inductive approaches favored by geologists, has even been carried to the extreme of arguing that Hutton's achievement can in fact best be appreciated by seeing him as primarily a moral philosopher.[9]

Opinions concerning the origins and significance of Hutton's theory of the earth would diverge less were the sorts of evidence normally used by biographers available, but as Hutton scholars have long lamented, almost none of Hutton's personal papers have survived. All of his major works—his theoretical essays on rain and on the earth, his two volumes on natural philosophy, the expanded version of his theory of the earth, and his three-volume work on epistemology—were published during the last decade of his life.[10] Even his surviving two-volume manuscript on the "Principles of Agriculture" was extensively revised in this period. Unfortunately, we have none of the drafts Hutton composed while hammering out his ideas, and since he was himself uninterested in revealing the sources of his thoughts either by citation or in autobiographical asides, those who wish to attach his published statements to their origins and contexts can at best suggest what appear to them to be the paths he followed during his long intellectual journey. Hutton's medical dissertation, which was published in 1749, offers one possible source of light in this dark landscape, but surprisingly it has been little studied.

The translation of Hutton's dissertation which follows is the first to be published and the Latin original is here reprinted for the first time also. In 1948 S. I. Tomkeieff advanced a sweeping and in many ways highly perceptive interpretation of the philosophical foundations of Hutton's geological theory, in the course of which he drew attention to Hutton's use of the concepts of the microcosm and of the circulation of the blood in the title of the dissertation.[11] It is evident, however, that Tomkeieff made no attempt to understand the text of the dissertation itself. More recently, François Ellenberger has published a long and detailed article describing both the circumstances in which Hutton prepared his thesis and the contents of the published work. Although Professor Ellenberger, assisted by his son Marc, prepared a French translation of the dissertation before writing this article, that translation has not been published.[12] With the exception of these two studies, Hutton's dissertation has been entirely neglected by the many commentators who have examined his geological and other philosophical doctrines.

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[5] P. A. Gerstner, "James Hutton's Theory of the Earth and his Theory of Matter," *Isis* **59** (1968): pp. 26–31, p. 31; *cf.* Robert Schofield, *Mechanism and Materialism* (Princeton, 1970), pp. 273–276.

[6] P. M. Heimann and J. E. McGuire, "Newtonian Forces and Lockean Powers: Concepts of Matter in Eighteenth-Century Thought," in Russell McCormmach, ed., *Historical Studies in the Physical Sciences* **3** (Philadelphia, 1971): pp. 233–306, pp. 246, 292–293; see also p. 287 and P. M. Heimann, "'Nature is a Perpetual Worker': Newton's Aether and Eighteenth-Century Natural Philosophy," *Ambix* **20** (1973): pp. 1–25, p. 22.

[7] J. E. O'Rourke, "A Comparison of James Hutton's *Principles of Knowledge* and *Theory of the Earth,*" *Isis* **69** (1978): pp. 5–20, p. 5.

[8] Roy Porter, *The Making of Geology* (Cambridge, 1977), pp. 185, 189.

[9] Anand Chitnis, *The Scottish Enlightenment* (London, 1976), p. 171. *Cf.* Eyles's assertion that "the methods Hutton had employed in forming his theory were essentially the same as those employed by modern field geologists," n. 3, p. 582.

[10] James Hutton: "The Theory of Rain," *Transactions of the Royal Society of Edinburgh* **1** (1788): pp. 42–86; *Dissertations on Different Subjects in Natural Philosophy* (Edinburgh, 1792); *An Investigation of the Principles of Knowledge, and of the Progress of Reason, From Sense to Science and Philosophy,* (3 v., Edinburgh, 1794); *A Dissertation Upon the Philosophy of Light, Heat, and Fire* (Edinburgh, 1794); and *Theory of the Earth: With Proofs and Illustrations,* (2 v., Edinburgh, 1795). For a complete listing of Hutton's published works and surviving manuscripts, see the bibliography in Eyles, n. 3, pp. 587–588.

But does Hutton's dissertation deserve more attention than it has so far received? Given its author's importance to the history of geology—Tomkeieff calls him the Newton of his field—it is slightly shocking to find that this unique record of his early thoughts has not previously been made available. But there are also more substantive reasons to insist that Hutton's dissertation be considered a historically important document. The history of geology is now experiencing a period of heightened interest and rapid growth. If the fruits of this new vitality are to meet the increasingly exacting standards of the history and philosophy of science, then the authors of the new histories of geology must do more than find antecedents of current ideas in the writings of their predecessors. A truly historical understanding of figures such as Hutton must identify the guiding concerns in their works, however foreign they may be to modern science, and then both explain how they evolved from the ideas of their predecessors and demonstrate how an understanding of these theoretical commitments can unify and deepen our understanding of their achievement. In Hutton's case such an approach carries the obligation to treat all his works together, as an *œuvre*, rather than isolating the geology from his other theoretical and philosophical statements. If future Hutton studies do in fact adopt this comprehensive approach, the dissertation will prove to be a most revealing document for the reconstruction, however tentative it must remain, of the history of his thought.

B. A Biographical Sketch

The few biographical details we have concerning Hutton's life are contained in the *éloge* his friend and disciple John Playfair prepared for the Royal Society of Edinburgh.[13] While the brief discussion of the development of Hutton's theory of the earth included in that sketch is suspiciously inductive,[14] the biographical facts Playfair provides suggest that Hutton had more than geological evidence in mind when formulating his theory. Particularly noteworthy is Playfair's repeated emphasis on Hutton's devotion to chemistry, and since chemistry looms so large in the dissertation, references to this facet of his philosophic interests will be given special notice in the following biographical summary.

Hutton was born in Edinburgh in 1726. His father, a merchant and former city treasurer, died three years later, leaving James and his three sisters to be reared by their mother, the daughter of another Edinburgh merchant.[15] The family had been left in comfortable financial circumstances and James in due course attended Edinburgh High School and, beginning in 1740, Edinburgh University.

Little is known of Hutton's three years as an undergraduate. He later recalled with pleasure the natural philosophy course taught by Professor Colin Maclaurin, the great mathematician and disciple of Newton, even though, as Playfair wrote, Hutton "cultivated the mathematical sciences less than any other" (39). He also recalled that it was in the course on logic and rhetoric taught by Professor Stevenson that he first discovered the fascination of chemistry. Apparently Stevenson illustrated some point by mentioning that while nitric and vitriolic acids can each dissolve the base metals by themselves, they must be combined to dissolve gold. In that instant, Playfair reports, Hutton recognized the scientific path he would follow for the remainder of his life.

> The instinct of genius, if I may call it so, enabled Mr. Hutton, young as he then was, to feel, probably, rather than to understand, the importance of this phenomenon; and as if, by the original constitution of his mind, a kind of elective attraction had drawn him towards chemistry,

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[11] S. I. Tomkeieff, "James Hutton and the Philosophy of Geology," *Proceedings of the Royal Society of Edinburgh* **63B** (1950): pp. 387–400, p. 396.

[12] François Ellenberger, "La Thèse de Doctorate de James Hutton et la Rénovation Perpétuelle du Monde," *Annales Guébhard* **49** (1973): pp. 497–533, and personal communication from Professor Ellenberger. We are most grateful to Professor Ellenberger for his generous encouragement and assistance in the preparation of this introduction and translation; see also below, Preface to the Translation.

[13] John Playfair, "Biographical Account of the Late Dr James Hutton, F. R. S. Edin.," *Transactions of the Royal Society of Edinburgh* **5** (1803): pp. 39–99; fasc. repr. in G. W. White, ed., *Contributions to the History of Geology* **5** (Darien, Conn., 1970); also repr. in *The Works of John Playfair* **4** (Edinburgh, 1822): pp. 33–118.

[14] See Arthur Donovan, "James Hutton and the Scottish Enlightenment—Some Preliminary Considerations," *Scotia*: American-Canadian Journal of Scottish Studies, **1** (1977): pp. 56–68, pp. 65–66, and Arthur Donovan, "James Hutton, Joseph Black and the Chemical Theory of Heat," *Ambix* **25** (1978): pp. 176–190.

[15] Eyles, n. 3, p. 577.

> he became from that moment attached to it by a force that could never afterwards be overcome. He made an immediate search for books that might give him some farther instruction concerning the fact which he had just heard of; but the only one he could procure, for a long time, was Harris's *Lexicon Technicum,* the predecessor of those voluminous compilations which have since contributed so much more to extend the surface, than to increase the solidity of science. It was from the imperfect sketch contained in that dictionary, that he derived his first knowledge of chemistry, his love for which never forsook him afterwards, and was in truth the propensity which decided the whole course and complexion of his future life (40).

In 1743, presumably upon completion of the arts curriculum, Hutton was strongly encouraged to prepare for a career in business. He secured an apprenticeship with a Writer to the Signet but "was often found amusing himself and his fellow apprentices with chemical experiments, when he should have been copying papers, or studying the forms of legal proceedings" (40–1), and he was soon let go. "The study of medicine, as being the most nearly allied to chemistry, was that to which young Hutton now resolved to dedicate his time" (41). From 1744 to 1747 he engaged in private study with a practicing physician while also attending lectures given by the medical faculty in the University.[16] He probably heard the chemistry lectures of Professor Plummer, but since the course was more pharmaceutical than theoretical, and notoriously uninspired, it is unlikely Hutton gained much by the experience.[17] In any case, towards the end of 1747 he departed for Paris "where he pursued with great ardour the studies of chemistry and anatomy" (41).[18] While in Paris he probably attended Rouelle's lectures on chemistry. Then, after nearly two years in Paris, he traveled to the low countries, submitted his dissertation and took his medical degree at Leiden, and returned to London.

Realizing that "the practice of medicine would [not] afford him that leisure for pursuing chemical and other scientific objects, which he fancied it would do when he saw things at a great distance" (42), Hutton quickly abandoned the profession to which he had so recently been admitted. He turned his attention instead to the manufacture of an industrial chemical, sal ammoniac (ammonium chloride). His partner in this venture was James Davie, a close friend of his in Edinburgh. "The turn which both of them had for chemical experiments formed their first connection, and cemented it afterwards. They had begun together to make experiments on the nature and production of sal ammoniac. These experiments had led to some valuable discoveries, and had been farther pursued by Mr Davie during Dr Hutton's absence" (42). The project was a success and the income Hutton derived from it, when combined with his inheritance, provided him with a comfortable independence for the remainder of his life.[19]

Upon returning to Edinburgh in 1750 Hutton decided to devote himself to improving a small Berwickshire farm his father had left him.[20] Before settling down he spent a year (1752–1753) living in Norfolk, where he studied the advanced agricultural practices of that area, and it was at this time, Playfair tells us, that he first became interested in mineralogy and geology. The following year he traveled in Holland, Belgium, and northern France and again closely observed both the husbandry and minerals of these regions. He then returned to his farm and devoted himself to introducing the agricultural practices that had brought such great advantage to England and the low countries. Of course he was not alone in this effort and in time he befriended the other improving landlords who lived nearby. In this way he became involved in a canal project, in geological excursions, and in other activities that occupied the progressive rural gentry of Great Britain in this era.

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[16] Hutton dedicated his dissertation to Dr. John Stevenson, a prominent physician in Edinburgh, not to be confused with the professor of logic of the same name, and Dr. George Young, his medical mentor; see Ellenberger, n. 12, p. 505 and Playfair, n. 13, p. 41.

[17] For a brief account of Plummer's course, see A. L. Donovan, *Philosophical Chemistry in the Scottish Enlightenment* (Edinburgh, 1975), pp. 37–39. See also, R. G. W. Anderson, *The Playfair Collection and the Teaching of Chemistry at the University of Edinburgh 1713–1858* (Edinburgh, 1978), pp. 5–10.

[18] It is not clear why Hutton chose not to complete his medical education in Edinburgh. Until the 1730s ambitious medical students accepted that a year in Leiden was practically mandatory, but by the 1740s Edinburgh had established itself as a first-rate center of medical education. Neither William Cullen nor Joseph Black felt obliged to study on the Continent. Hutton may have found it advisable to leave so as to avoid scandal. Although he never married, he fathered a son around 1747. The mother's identity remains unknown but she may have been a woman of some standing. Hutton supported the child, who bore his name, and many years later Joseph Black, who apparently did not know Hutton before 1768, could write that the son, then about fifty years old, "is not unlike the Dr. in person and bald like him but not like him in the face, having more of the features of his mother." Eric Robinson and Douglas McKie, eds.,, *Partners in Science: Letters of James Watt and Joseph Black* (London, 1970), p. 277.

[19] The chemical business was carried on in Davie's name alone until 1765, when Hutton became a legal partner; Playfair, n. 13, p. 46. We know from a letter by Joseph Black that the chemical works established by Hutton and Davie was still in operation in 1783; see Archibald and Nan L. Clow, "Dr. James Hutton and the Manufacture of Sal Ammoniac," *Nature* **159** (1947): pp. 425–427. In the *Supplement to the 4th, 5th and 6th Editions of the Encyclopedia Britannica,* (6 v., Edinburgh, 1824), Thomas Thomson states that "this original manufactory [of Hutton's and Davie's] existed in Edinburgh till within these few years," **1**: p. 246.

[20] As Playfair notes, "the motives which determined him in the choice of the latter [i.e., the farm], cannot now be traced with certainty" (43). It is worth noting, however, that before deciding to settle in Berwickshire, "he wrote on the subject of his future prospects with considerable anxiety to his friends in Edinburgh" (42). It may be that his reputation had still not been cleared in Edinburgh. When Hutton finally settled in Edinburgh in 1768, he lived in a household managed by his three unmarried sisters.

In 1768 Hutton leased out his farm and moved to Edinburgh to give "his undivided attention . . . to scientific pursuits" (46). He settled in with his sisters and was soon accepted into the society of natural philosophers and literati that made Edinburgh such a brilliant center of intellectual life during the latter half of the century. His closest friends were the chemist Joseph Black and the economist and moral philosopher Adam Smith, both of whom were, like Hutton, bachelors, but through his membership in the Philosophical Society and other clubs he encountered and befriended a large circle of fellow philosophers. And yet unlike the great majority of his colleagues, Hutton neither held office in the Church, university, government or courts of law nor published anything of significance during the 1770s and early 1780s. But as Playfair makes clear in a passage that conveys beautifully Hutton's situation, these were years of great philosophical activity.

> Employed in maturing his views, and studying nature with unwearied application, he now passed his time most usefully and agreeably to himself, but in silence and obscurity with respect to the world. He was, perhaps, in the most enviable situation in which a man of science can be placed. He was in the midst of a literary society of men of the first abilities, to all of whom he was peculiarly acceptable, as bringing along with him a vast fund of information and originality, combined with that gayety and animation which so rarely accompany the profounder attainments of science. Free from the interruption of professional avocations, he enjoyed the entire command of his own time, and had sufficient energy of mind to afford himself continual occupation (46).

Chemistry was one of Hutton's chief occupations during these years. "Dr Hutton was a good chemist," Playfair tells us, and "a good deal of his leisure was now employed in the prosecution of chemical experiments" (51, 47). Sometime before 1772 he identified the alkali in the mineral zeolite, a clear demonstration of his ability as a laboratory chemist (47). But for Hutton chemistry was much more than a laboratory science. A student who called on him in 1772 reported that "his study is so full of fossils [i.e., rocks and minerals] & chemical apparatus of various kinds that there is hardly room to sit down. . . . He is a most enthusiastic chemist. He actually acknowledges having tried to discover the Philosopher's Stone."[21] Whatever the secret hopes that motivated this attempt, Playfair had no doubts that for Hutton chemistry provided the key to the natural world.

> He tells us himself, that he was led to the study of general physics, from those views of the properties of body which had occurred to him in the prosecution of his chemical and mineralogical inquiries. In those speculations, therefore, that extended so far into the regions of abstract science, he began from chemistry; and it was from thence that he took his departure in his circum-navigation both of the material and intellectual world (74).

Hutton's other major concern during the first decade and a half following his return to Edinburgh was the study of the earth. He took a geological tour through parts of England and Wales in 1774, studied and wrote a pamphlet on the qualities of coal, read a paper on certain features of the prominent Edinburgh hill called Arthur's Seat, collected minerals, and poured over descriptions of landforms contained in travel books (47–51). There can be little doubt that the facts about minerals and landforms Hutton collected so avidly were already being ordered and interpreted by an early formulation of his theory of the earth. Joseph Black, in a letter written in 1787, describes Hutton's mature theory in detail and then adds that "Dr. Hutton had formed this system or the principal parts of it more than 20 years ago: & he has found reason to be more and more confirmed in it by the study of fossils ever since that time," a view supported by Playfair's testimony as well.[22] Clearly Hutton's failure to publish anything of theoretical importance between 1749 and 1785 cannot be taken as an indication that he had nothing of interest to say.

During the middle years of the 1780s Hutton became a more active participant in the institutional life of the Scottish Enlightenment. The particular focus of his activity was the Royal Society of Edinburgh, chartered in 1783, which had, as Playfair noted, "the good effect of calling forth from Dr Hutton the first sketch of a theory of the earth" (50).[23] After presenting his theory before the Society in 1785, Hutton embarked on a series of geological excursions in the company of one or more of his aristocratic friends.[24] These journeys through the Scottish countryside and the Isle of Man were perfect anticipations of the more widely publicized geological excursions of the following century and must have been delightful in themselves, but for Hutton they had a more serious philosophical purpose as well. He was, Playfair says, "anxious that an *instantia crucis* [i.e., crucial observation] might subject his theory to the severest test" (67), but he found nothing in the record of the rocks that obliged him to change his mind.

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[21] B. Cozens-Hardy, ed., *The Diary of Sylas Neville 1767–1788* (London, 1950), pp. 146, 153.

[22] William Ramsay, *The Life and Letters of Joseph Black, M.D.* (London, 1918), p. 124; Playfair, n. 13, p. 51.

[23] Evidence of Hutton's frequent participation in the Society's affairs is contained in the MS "Minutes of General Meetings of the Royal Society of Edinburgh from its Institution, June 23, 1783, to July 6, 1791," Royal Society of Edinburgh. Arthur Donovan has recently stated that from 1782 to 1784 James Hutton was a member of the so-called Chapter Coffee House Society in London (see n. 14, *Ambix*, pp. 186, 190 n. 3; and his "Scottish Responses to the New Chemistry of Lavoisier," in Roseann Runte, ed., *Studies in Eighteenth-Century Culture* 9 (Madison, Wisconsin, 1979), pp. 237–249, p. 248 n. 5). It now appears this claim, based on a partial transcript of a MS in the Oxford Museum of the History of Science, cannot be sustained. According to Dr. Hugh Torrens, who has kindly conveyed this information in a private communication, additional evidence contained in the Chapter Coffee House Society Minute Book clearly indicates that the "Dr. Hutton" referred to was Charles Hutton, who had been appointed professor of mathematics at the Woolwich Military Academy in 1773.

[24] Playfair, n. 13, pp. 67–74. The definitive account of Hut-

The final phase of Hutton's life began with a severe attack of bladder stones in 1791, an ailment that recurred thereafter and forced him to remain in his house after 1794.[25] He remained alert, however, and spent his time reworking and preparing for publication what must have been a mountain of treatises in manuscript that he had been working on for decades (74n).[26] All Hutton's books were published between 1792 and 1795. As his life drew to a close he was particularly troubled by Richard Kirwan's criticism of his geological theory, a response that in Hutton's opinion was closely tied to the political and chemical revolutions originating in France. Playfair reports that "the very day . . . after Mr. Kirwan's paper was put into his hands, he began the revisal of his manuscript, and resolved immediately to send it to the press" (86). The details of Hutton's refutation are of less concern to us here than his more general complaints. He charged that "in this political age, the study of nature seems to be but little pursued by our philosophers" and that his critics were "superficial reasoning men" who "judge of the great operations of the mineral kingdom, from having kindled a fire, and looked into the bottom of a little crucible."[27] Science in general and chemistry in particular were being adapted to a new era and geology would soon be recast along similar lines also. But so long as his strength lasted Hutton continued to prepare for publication the comprehensive theories that had been the central concerns of his life. The first two volumes of his expanded theory of the earth were issued but the final two did not make it through the press in his lifetime.[28] At the time of his death in 1797 Hutton was working on his two-volume "Principles of Agriculture," which has never been published.

PART II—THE DISSERTATION

Conceptually, Hutton's dissertation invites analysis along at least four thematic lines. First, several of its statements illuminate what we might call his philosophy of nature, that is to say, his views on the defining characteristics of the natural world and their relation to God's providence and man's existence. Second, Hutton's manner of constructing arguments, in addition to several direct statements, reveals a good deal about what we will call, somewhat anachronously, his philosophy of science. How can one best employ reason and observation to gain an understanding of the operations of nature? Hutton's clear recognition that this latter question has to be treated independently from our beliefs about God and nature is, I believe, a fact of considerable interest. Third, Hutton's long section on chemistry makes possible an analysis of his views on the fundamental concepts and concerns of this science. Fourth and finally, his physiological and pathological doctrines enable us to locate his ideas on these topics both within the context of his own thought and in the history of medical theory.

A. Philosophy of Nature

Rather than minimizing the role played by his philosophy of nature, Hutton gave it a prominent place in the title of his dissertation. Had he wished to present his work solely as a medical investigation he could have titled it "On the Blood and its Circulation in the Body," but he chose instead to speak of "The Blood and the Circulation of the Microcosm." Clearly the word microcosm is being used here as a synonym for the human body, as it is elsewhere in the dissertation (LXXXII, XCI), but the term also introduces connotations not necessarily associated with the less burdened phrase human body. The foremost of these is the assertion of order and systematicity, cosmos as opposed to chaos. Another is the implication of two orders, the micro and the macro, and when describing how the nutrition of plants is related to the nutrition of animals and man, Hutton speaks of "the very nice circulation of the macrocosm" (LXXVIII). Further questions suggested by these connotations are: What are the principles of order in Hutton's conception of the micro and macrocosms and what are the relations between these two realms of order?

The answer to the first of these questions is cyclicity. The body displays "the glorious cycle of life" in being unending, which is to say it is self-activating, self-fulfilling, self-replenishing, and self-reproducing (II). In acting in this way the body completes "its role in the microcosmic grove" (II) and demonstrates how it is to be understood within the larger realm of nature. For nature, Hutton insists, is "most carefully arranged" and "carries this bright quality in all of its traces, in that, just as all of its

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ton's excursions and reproductions of the drawings made by several of those who accompanied him are presented in chapters 3 and 4 of G. Y. Craig, ed., *James Hutton's Theory of the Earth: The Lost Drawings* (Edinburgh, 1978).

[25] Eyles, n. 3, p. 579 n. 4, corrects Playfair, who said the initial attack occurred in 1793.

[26] In his 1787 letter on Hutton's theory of the earth Joseph Black said "the paper he has published in our *Transactions* is but a specimen; he is preparing a larger work." Ramsay, n. 22, pp. 124–125.

[27] Hutton, *Theory of the Earth,* n. 1, 1: pp. 250–251.

[28] Chapters 4 through 9 of volume III survived and were published in London, 1899, ed. A. Geike.

general mechanisms rejoice, so also do all of their various smallest component parts rejoice in the depth of wisdom, in the height of perfection, and in the lofty arrangement of forms and qualities" (I). In this ornate paean Hutton also hints at the only answer he will give to our second question. The microcosm and the macrocosm share the common property of cyclicity, but beyond that Hutton will not go. Clearly there must be linkages, such as those that join the nutrition of the individual body to the food chain in nature, but Hutton does not spell them out. Neither does he suggest any pattern of correspondence or material connection between the two realms of order. The terms microcosm and macrocosm are employed but the astrological and alchemical implications that gave them elaborate significance in previous centuries have been silently sloughed off.

The concept of cycle emphasizes closedness and perfection, that of circulation stresses movement, and circulation is the central activity of the cycles Hutton discerns in nature. While the overall concern of the dissertation is the "great circulation," that "marvelously involved journey" (LXXVII) by which the blood achieves "its vital flow and the functions that depend on it" (XL), Hutton concentrates his attention on the sub-systems of circulation which, when taken together, comprise the whole. Being convinced that there are microcosms within the microcosm of the body, he describes the "nutritional circulation" that flows "in muscles, in membranes [and] in bones" (XLVIII) and the "circulation of the glands" which both nourishes the organs and glands of the body and supplies the juices which, when properly modified, they secrete (LXVII, XLIX). A sub-circulation within this latter system arises in the brain, where a highly refined fluid is separated from the blood and then sent out to circulate through the nervous system (LII). The nutritional circulation also gives rise to two distinct systems of sub-circulation, one through the spleen and the other through the liver (LXIX, LXX). And finally, after all these fluids have completed their appointed rounds and have returned to the heart, the blood is sent through the "pulmonary circulation" to be restored to its original quality (LXXII–LXXVII).

The dynamic agents that drive these circulating fluids onwards are quite various. Unlike the iatromechanists and iatrochemists, who opposed each other in a highly partisan manner, Hutton accepts that the body is governed by "physical, mechanical, and chemical laws" (I, IV). For instance, the blending of chyle and blood involves both "a chemical and mechanical reaction" (LXXVI), while pathological conditions of the blood can arise from an imbalance between the acids and alkalis (LXXXIV–LXXXV), from a loss of elasticity and muscle tone in certain solid parts of the body (LXXXVIII), or from an infection located elsewhere in the body (XC). But more revealing are those phenomena for which the known laws of mechanics and chemistry are demonstrably inadequate, for in seeking to explain them Hutton refers to the additional causative agents he believes operate in nature. Consider, for instance, the theory of muscular action. After briefly surveying the received mechanical and chemical explanations of this phenomenon Hutton declares them all fanciful or insufficient and adds that "here it is absolutely necessary to call on the aid of some active and potent cause which is, perhaps, entirely different from any chemical, mechanical (etc.) law thus far known to us" (XLIII). The cause he has in mind is "a simple contraction of the component elastic fibers against themselves." The highly specific character of this cause is made plain when Hutton insists that muscular movement "is accomplished by a fairly great increase in their contracting, elastic power whereby they naturally contract." But if the power of contracting is a natural property of muscular fibers, it must be triggered by some external agent, and this assignment Hutton gives to "the fluid of the nerves together with the collaboration of arterial circulation" (XLIII).

For our purposes, the adequacy of Hutton's theory matters less than the light it throws on his basic understanding of the causes acting in nature. Realizing that attributing a contractive power to muscle tissue hardly constitutes a convincing explanation, he goes on to suggest two ways in which this power might be explained in a more general way: "This power of contraction depends upon some hidden material law which has not yet been clearly enough observed by us or it is effected by virtue of some subtile active medium which very readily penetrates all bodies but acts upon them under certain conditions of theirs" (XLII). Whichever of these two modes of general explanation may prove to be true, and he is hardly in a position to settle the issue, they both share the property of being material causes. Either of these causes could also act in either of two modes. Either it could be the origin of the contractive power itself or, like the nerve fluid, it could act instrumentally by causing the power to manifest itself in certain circumstances (*cf.* his instrumental account of nutrition, XLII). Such are the efficient material causes, specific and general, actual and potential, that in Hutton's view constitute the active agents in nature.

The first and final cause in nature is, of course, to be found in God. Nature itself is the work of "a benign omnipotent God" (I) and contains within itself no evidence of disorder or evil. But nature, like God, is not transparent to the human mind. Its intricacy and complexity are such that it surpasses human understanding, its inner workings lying "far beyond every investigation of the human mind" (I). And yet Hutton's nature is not essentially mysterious, in the sense of operating in ways unknowable by man. Man has the ability to gain reliable knowledge about God's world but he lacks the capacity to know it exhaustively. Thus man should stand before the God of nature in humility but without abasing himself, realizing that "it is not at all proper to go too far with the imagination whenever nature's plan exceeds our talent" (XLIII). But if in principle the human mind is capable of grasping the inner workings of nature, then surely these workings must be complete in themselves and must not be subject to chance or be rendered inscrutable by the intervention of God's will. Hutton faced this central issue in eighteenth-century Newtonianism squarely when he stated that gravity, the subject of the most general of all natural laws, "either operates by means of a material law, that is, under the auspices of a subtile medium, or it depends immaterially and immediately upon the will of the almighty Godhead" (XLIII). But he had the good sense not to entangle himself in theological disputes and left it for his readers to see that given what he says elsewhere about the order of nature and the action of material causes, his position in this debate can hardly be in question.

B. Philosophy of Science

Although the inner workings of nature are ultimately knowable, they are not revealed by simple inspection, and thus men, being incapable of immediate knowledge, must use a mediating method if they are to understand natural phenomena. The method Hutton employs, as exhibited by the structure of his dissertation and in the several methodological asides it contains, involves essentially the three steps of differentiation, abstraction, and analogy.

Beginning with the assumption that blood is "a highly compounded liquid containing many different homogeneous parts, of which one species is quite distinct from another with regard to form and quality" (IV), Hutton proceeds to isolate, identify, and characterize these simple constituents. He uses the microscope to see the "little red spheres" and the "smaller ones which are nearly transparent" that float in the blood (V). Then, examining the changes that take place in blood removed from the body, he differentiates between the clotted matter, "which takes on a thick, fibrous consistency," and the serum, which "retains its fluidity" (VI). Each of these substances is then subjected to heat and the action of various chemicals while the changes induced are duly noted (VIII–XII).

Hutton then moves on to a more general level of differentiation and attempts to identify the simple constituents of all living things. These he says are "salt, water, sulfur, earth and air" (XIII). But note that he calls these substances principles, by which he means the most simple substances that can be identified by chemical analysis, not elements. "We are not entirely sure," he argues, "that these principles are basic, original and immutable elements; being merely specific differentiations of the animal or the vegetable kingdom, they should not be taken any further by means of human skill" (XIII). Whether elementary or not, however, these principles, once identified, can be characterized in terms of their dominant properties, and it is at least conceivable that these properties will endure in compounds formed from the simpler principles, thereby explaining the properties of the compounds. But Hutton sees little hope of success in proceeding this way. "Although every pure principle enjoys its own particular powers, still, when it is united with other things in a compound of blood, it cannot act independently upon external bodies applied to it but only through the combined capacity of their mutual union" (XIV). Analysis, if conceived of as the separation of substances into the simplest components we can obtain, is an insufficient method for the investigation of natural phenomena, for it does not yield the first principles needed for a synthetic or deductive understanding. In Hutton's words, "it is then not possible to make a completely sure *a priori* judgment concerning the nature and the quality of the blood, even though the principles of the blood be known, as well as their actions and appearances" (XV).

Since differentiation at the phenomenal level is inadequate as a scientific method, Hutton also employs the method of abstraction. His goal is to identify essential qualities, that is, the properties of substances that cause and therefore explain the phenomena we encounter in the natural world. But rather than defining these qualities geometrically, as did the Cartesians, he further refines the verbal concepts already introduced. His use of this method, and his reluctance to coin new terms, results in the addition of a new level of meaning to the term principle. The ambiguity thus introduced, which was commonplace in eighteenth-century chemistry, made possible a good deal of rather imprecise hypothesizing. For instance it enabled Hutton to claim that the saline principle in blood, for the existence of which we have good experimental evidence (XXV), is the same principle compounded "not only with vegetable matter but also with the mineral kingdom" and that it "is the true primary acid salt from which all other salts, being derivatives of it and compounded to a greater or lesser extent, originate" (XXIV). This general conclusion refers both to salt's essential active property of being an acid and to its defining taxonomic property of solubility, and it asserts that both these properties are evident, if in a reduced state, when the principle salt is compounded to form other substances. But once a theory of chemical dynamics had been attached to this taxonomic scheme, the implications of the explanatory theory for the classificatory categories could not be avoided. It was commonly held, for instance, that the defining property of the principle earth is resistance to volatilization in intense heat. But, Hutton points out, a portion of fixed alkaline salt (solid potassium carbonate) also exhibits this property. Therefore, "if we were to characterize the principle [earth] by its properties and immutable nature, then there would be found many bodies which differ greatly but which claim this dignity with an equal right" (XIX). This confusion of the taxonomic categories of earth and salt then allows him to explain the activity of earth in terms of its salt, as will be seen below. For Hutton, as for other eighteenth-century natural philosophers who sought to explain chemical change, the principles isolated by chemical analysis and the active principles of matter were easily distinguished, yet somehow they had to be brought together into a common system of chemical principles.

Although the method of abstraction Hutton used created ambiguities and raised problems, it also provided rewards of fundamental importance to his science. However we may choose to evaluate the conclusions he reached, Hutton clearly found them satisfying. At the end of his discussion of the saline principle he declared with great confidence that "from what has been stated it is clear why no fixed alkali is given off by whole blood; why, although no volatile salt in a natural state is found in the blood, nevertheless, by a chemical operation it is so readily supplied from it." And so he continues, explaining with great assurance a variety of properties of the blood (XXIX). In a similar way he believed his knowledge of the essential properties of salts, especially volatile alkali (ammonia) salts, enabled him to explain in great detail the production and chemical characteristics of urine (LXV). Here then we have instances where, in Hutton's opinion, the method of abstraction, as practiced by the chemists of his age, provided first principles for the construction of genuinely scientific explanatory theories.

But what procedure should be followed in cases where it is much less clear how one can move from an analysis of constituents to first principles? This problem is particularly pressing in investigations of phenomena that cannot be explained by the established laws of mechanics and chemistry. The secretions of the brain, for instance, while "the most important and of the greatest necessity," can only be known "by reason and analogy." But reasoning by analogy, while our only recourse in such cases, is an unsure business, for what little we know about the brain, to continue the example, is "extremely obscure, controversial and, indeed, not the least bit demonstrable" (LI–LII).

There are cases, however, in which reasoning by analogy may suggest causes that, when operating under particular circumstances, begin to explain the phenomena under examination. We know, for instance, that the blood contains a considerable quantity of condensed air, but how air loses and regains its elastic properties has not been adequately explained. If we assume with the Newtonians of Hutton's generation that air is "a mass of particles endowed with a certain repellant force, etc., and that this repellant force depends upon a definite disposition of the air particles" (XXXVIII), then we can look elsewhere in nature for the operation of an analogous force. The analogy Hutton chose was the recently developed field of the interactions of bodies charged with static electricity: "Two electrified bodies repel one another but, if the electricity is removed from one of them, they are attracted to one another, if it is removed from both of them, they are neither attracted nor repelled" (XXXVIII). Then, after illustrating the electrical analogy with an experiment, he makes explicit the analogical relationship: "In the same way elastic particles of air which are repellant can, when combined with other heterogeneous particles, lose their elastic or repellant quality and result in blendings as solid inelastic compounds and yet later on, after being disentangled by the activity of fire or fermentations, they can once again recover their former elastic quality" (XXXVIII). Finally, analogy having illuminated the process, Hutton identifies the particular causal agents that bring about the fixation of air: "It is probable that in this fashion a very large amount of the air's elasticity is destroyed in the lungs, etc. by animal vapors, or by other sulfurous vapors which, when thoroughly blended with the air, can combine with its particles and adhere to them, destroying or at least substantially reducing their elasticity in the manner already stated" (XXXVIII).

Hutton again turns to electricity in his effort to understand muscular contraction. In his search for the "hidden material law" or "subtile active medium" (XLIII) that governs the movement of the muscles, he cautiously circles in on his target. First he introduces by way of analogy "the phenomenon of thunder" which "teaches the amazing effect of subtile media upon bodies that are endowed with a peculiar modification." Having thus indicated it is a "subtile active medium" that causes muscular motion, he mentions light and heat before settling down to an examination of electricity: "The phenomena of electricity nicely illustrate how much two bodies in a mutual application can modify so potent a medium" (XLIII). The relevant electrical phenomenon is then illustrated by an experiment, following which Hutton reveals, in the form of queries, that he is not quite able to decide whether electricity is the cause of muscular action or whether it provides no more than a very close analogy to that cause. Thus he asks, "can an animal be considered to be a kind of electrifying machine? insofar as it will be constituted of non-electric and electric parts," and "can the nature of this [electrical] force [generated in animals] be such that it causes the muscular fibers to contract powerfully?" But when one looks at the operations that take place within the body, claims of identity must be reduced to hypotheses suggested by analogy: "Can the friction of the blood's globules against the walls of the capillaries excite a force analogous to electricity," and "can this force be so modified by a special application of electrical solids and non-electric fluids that it can produce an effect which is occasionally strong, analogous to an electric shock" (XLII)? Identity or analogy? In the case of electricity and muscular motion Hutton did not believe he had sufficient knowledge to decide.

C. Chemistry

An examination of natural phenomena reveals the operation of two distinct sets of causes, "mechanical form" and "chemical action" (IV). Since blood is a product of animal life, Hutton naturally founds his theories upon chemistry, the science of active matter. He then takes the initial analytic step of differentiating the subject of his study into its simplest chemical substances, in this case the five constituents which in combination form all the matters found in the animal kingdom: salt, water, sulfur, earth, and air (XIII).

This set of simple components in fact contains substances of two distinct sorts, those that are elementary and act as instruments of chemical change and those that possess essential chemical properties. Water, for instance, is clearly irreducible and everywhere "the same simple element" (XVII). It is also the most prominent component of blood, accounting for 73 per cent of its weight (XII), and serves both as an instrument of liquidity and as a constituent in the compounds of the blood: "The water of the blood not only enters into the composition as the menstruum and the vehicle for the other elements, . . . but it even enters into their minute solid combinations and into their blendings which are almost primary" (XVI). Air is another elementary and instrumental component of blood. Its standing as an element is well-established: "As the notion or definition of air is quite obvious and the name of element is universally accepted, it will then be foreign to the main theme to attempt to question its elemental right here" (XXXVI), and its presence in the blood is easily demonstrated: "By distillation and putrefaction air is obtained from blood in a fairly large amount" (XXXVII, *cf.* XII). Instrumentally, "the vivifying virtue of air depends solely upon an alternating distension of the lung" (XXXIX, *cf.* LXXV), where its elasticity promotes respiration, which in turn serves to blend together the depleted blood and the nourishing chyle (LXXIV). But when combined in the blood, air has no essential role to play: "By no means is [fixed] air found . . . to be so very necessary to animal life" (XXXVII).

The principle sulfur is a transitional substance, serving in one capacity as a physically simple and instrumental cause and in another as a bearer of essential chemical qualities. It is not, of course, the same thing as the common substance we call sulfur. The principle "is, to a large extent, easily separated from the compound of the blood by the application of fire and free communication with the air, but then it cannot be contained in the pure state" (XXXI), whereas in common sulfur the principle is combined "with a saline substance perhaps, and with a small amount of a certain peculiar watery combination" (XXXII). In its pure state the principle first "presents us with a sensation of light and heat" and then disappears, behavior that leads us reasonably to conclude that "it is, then, the matter of fire and light which pervades everything" (XXXI). But note that Hutton has not called this "matter of fire and light" an element, and it seems likely, given what we know of his views on electricity and gravity, that he saw it as but one manifestation of the one or more subtile media acting in nature. But at least instrumentally sulfur is the source of fire and heat, the most important analytical agents in chemistry (*cf.* VIII, XII).

The salt principle is most evidently a bearer of significant and essential chemical properties. First, because it is the same principle that is present in all realms of nature: "Blood has a saline principle in common not only with vegetable matter but also with the mineral kingdom" (XXIV). Second, because it has the unambiguous defining characteristic of solubility: "Anything of an earthen nature that is found in a dissolved or liquid form, that alone is caused through the aid of this one principle" (XXIV). Third, because, being the bearer of the essential chemical property of acidity, it is the substance from which all observable salts are derived: "This is the true primary acid salt from which all other salts, being derivatives of it and compounded to a greater or lesser extent, originate" (XXIV). Naturally this "true primary acid," although real, is known only by reasoning from its effects and cannot be isolated (XXV). But it is the most chemically active of the principles, for it "enters into mixture or composition with all the vegetable and animal oils" and "when, in addition, it is joined to their particular earths and oils, it forms their various compounded salts" (XXVI).

Earth, unlike salt, is not an easy principle to define. It "provides so difficult an occasion for speculation and one which is cloaked in so much obscurity that it certainly should not be undertaken without seriousness" (XVIII). Hutton appears to be most troubled by the tradition of defining earth in terms of "two merely negative and passive items" (XVIII), namely its resistance "to fire and water" (XIX). He is not disputing the observation that those substances usually called earthy are insoluble and cannot be volatilized by fire, rather he is unwilling to see a chemical principle defined, as is Newtonian matter, as essentially inert. He therefore returns to the phenomena and begins again by abstracting the active properties of earth from the effects it exhibits in observable compounds. He notes, for instance, the "weakening of the power of the saline principle in combination" with earth and finds in this effect evidence of an active power of earth (XIX). He then defines earth in terms of its "affinity" for salt and its traditional passive qualities: "By earth, a principle of the blood, we understand a body fixed in itself and insoluble in water, having a great affinity and reaction with the saline principle, through whose aid it is rendered soluble in water and blends with other bodies" (XX). Having thus brought earth into the realm of the active principles, Hutton indicates what effects its presence engenders in compounds. When combined "with a saline principle and perhaps with water" it yields alkaline salt, and this compound, when further combined "with sulfurous or oily matter, produces volatile alkali" (XX). But the entire subject is vastly complex and quite obscure (XX–XXI), and while Hutton believes he has taken an important step towards a more adequate conceptualization of the principle of earth, he is well aware of the difficulties that remain.

The sulfur principle "enjoys a nature and properties which are more distinctive than the others, and it does not have the similarity with them that we saw exists between the salt and the earth" (XXX). Its properties as the instrument of fire have been described above, but in chemical compounds, when it is "combined with and, as it were, embodied within principles, it loses its own igneo-luminous qualities until it again be freed from them by an application of fire" (XXXI). It exhibits its essential properties in a variety of compounds, being the dominant ingredient in alcohol, niter, sulfur, volatile alkali, vitrescent earth, and metals (XXXII; for metals, *cf.* XXVII). In the animal economy, and more specifically in the blood, the most important compounds containing sulfur are the various oils produced within the body (XXXIV–XXXV).

How, after abstracting the essential characteristics of the principles from their perceivable effects, did Hutton explain their actions? The element water has as its essential power the ability to dissolve substances and its role as an instrument therefore depends on its serving as "the medium" in which other constituents of the blood act and on providing the blood with "the basis of its fluidity" (XVI). But the action of the air was not so easily ascribed to an essential property. As we saw above, Hutton insisted that air contributes to the circulation and revitalization of the blood solely through its elastic inflation of the lungs, air which has lost its elasticity and become fixed in the blood being of no discernible significance. But is this active power of elasticity an essential property of air? Since air loses this property when fixed in solid or liquid substances, can it be considered a property unique to air that is masked during fixation, or is air's elasticity a manifestation of some other power? And if elasticity is not a power of air alone, is there such a thing as elementary air, or is air simply composed of particles that happen to possess the property of elasticity when in a particular conformation? Or, to put this question in the terms commonly employed in the eighteenth century, is there a real difference between true permanent air and vapors?

Hutton takes up this troubled question by asking "whether the same item [i.e., air] which entered into a compound with the bodies be separated from them or whether it be generated anew" (XXXVI)? He then adds that "one who prefers this latter hypothesis can readily point out the possibility of such a generation from the phenomenon of the expandable vapors of boiling water, which produce, temporarily, an appearance but then the true character of the air" (XXXVI). But the appearance is deceptive, for such vapors "do not endure." But in Hutton's mind the very existence of this debate is an indication that the elasticity of air must be explained by a more fundamental set of causes. The first set of causes he mentions are chemical: "What if one were . . . permitted to give an opinion regarding its [i.e., air's] composition, to judge it . . . to be a peculiar combination of a sulfurous principle and water" (XXXVI). He then uses this supposition to suggest an explanation of air's role, presumably chemical and essential, in the growth of plants: "Wouldn't this shed some light on the nutrition of vegetables through inspiration" (XXXVI)? But since air does not combine chemically with the blood, the sulfurous principle in animals being obtained from vegetable foods, the problem of explaining "how so great an abundance of air can be condensed and stay in the blood in so inert a state" remains (XXXVIII). It is at this point that Hutton introduces the electrical analogy described above to explain how the mechanical mixture of certain substances with air particles has the effect of "destroying or at least substantially reducing their elasticity" (XXXVIII). After thus suggesting two ways in which the elasticity of air, and its loss, might be explained in terms of more fundamental causes, Hutton leaves the theoretical issue unresolved and ends his discussion of air with a rambling description of the effects air deprived of its elasticity has upon the animal economy (XXXIX).

Sulfur, when acting as an instrument, is the source of heat and fire, agents which, like water, have long been considered fundamental causes of chemical change. Within animal bodies this instrument manifests itself as "a putrefying fermentation" which, Hutton claims, is entirely analogous to fire: "Regarding this operation let us merely observe that in this respect it provides the same resultant reaction as does fire; and in this phenomenon as well as in many other it seems to operate like fire or a secret combustion in the subject's entrails" (XXVIII). This "animal fermentation" not only furnishes "the heat of digestion" (LXIX), it is "the body's vivifying faculty" (LXV, #4) that urges forward those mechanical changes and chemical reactions that take place in the physiological systems of animals. For instance, the volatile ammonia obtained from urine "must be considered as a true creation of the blood only and the result of animal fermentation (by which we suppose it to be just a loosening and combining power)" (LXV, #2). Thus the matter of fire contained in sulfur is the bearer of one of the most fundamental and most potent powers in nature.

The chemically active principles, that is salt, earth, and sulfur, act upon each other through neutralization and displacement. A "saturated, or so-called 'neutral' combination" is formed when acidic and alkaline substances react. Hutton considers this reaction self-explanatory, for "it is, indeed, not very difficult to conceive of the quality and the phenomena of an acid and an alkali as being opposed" (XXVII). He indicates that in his opinion the mechanistic explanations of the corpuscularian chemists do not deserve serious consideration, saying that "at this point I am apologetic for merely making mention of spiculae and pores, of sword and sheath: from this source too, one notices how the old struggles and suppressions of acid and alkali rise up anew" (XXVI). Such hypotheses add nothing to our understanding of the intense activity and profound changes that occur in acid-alkali neutralizations. When such naturally opposed substances are mixed, "a very strong and vivid interaction occurs between them, so that, when blended in a dissolved state, they rush together with vehemence and boiling and become saturated, that is, they effect a compounding that produces no further combining activity with acid or alkali" (XXVII).

The substances formed by neutralization, while entirely unlike the components from which they were formed and while relatively inactive, are not altogether inert. If such a compound is exposed to a simpler, in the sense of a more perfect or purer, acid, or alkali, the cruder component in the combination will be displaced,

> for it is always the case that the simpler the combining parts, so much stronger will be the combination, other things being equal; and this can be taken as a general rule in chemistry: thus, when the acid salts of niter, sea salt and vegetable items are compounded, they combine with alkali salt more or less firmly in accordance with the strength of each one; but they all yield to vitriolic acid, because being simpler, it therefore produces a stronger reaction upon an alkaline body (XXVII).

Similar displacement reactions can be demonstrated with the metals in acid solutions, but here Hutton warns against a false analogy. In his view the principle of metallicity is, like that of alkalinity, a compound of the sulfur and earth principles. Thus, he argues,

> we should note here that this rule [of displacement] takes place and is to be applied only when different bodies act upon a common body with one and the same principle, . . . but the situation is otherwise when a simpler body, such as silver dissolved in spirit of niter, is precipitated in a more compounded body, such as copper; in this case one must take many other factors into account, for spirit of niter reacts upon the none-too-simple sulfuro-earthy principle of metals; but the metallic principle being quite complex, copper, for instance, can differ a great deal from silver (XXVII).[29]

D. Medicine

In medicine as in chemistry the road to understanding begins with analysis. "The animal economy can be analyzed into these functions, namely, sensation, muscular movement, nutrition, the propagation of the species, the production of blood, and the generation of heat" (III). But useful as analysis may be, we should not let it deceive us into thinking that the functional systems of the body operate independently. In fact, "these functions take place not at all in isolation but interdependently, in a remarkably complicated manner" (III). This complexity in turn means that the active agents of these various functions will not be completely separable and that we must be ready to accept multiple causation when explaining how the circulation sustains these functions. We have already looked at several instances in which Hutton attempts to explicate the relationship between fundamental active powers in nature and certain specific physiological functions, such as muscular motion. A glance at other doctrines he uses in dealing with problems in medical theory will further illuminate the pattern of his thoughts about science and nature.

Consider, for instance, the tasks Hutton assigns to the nervous fluid. This fluid, after being separated from the blood in the brain, circulates through the system of nerves "into every point of the body for the benefit, perhaps, of sensation, muscular movement and nutrition" (III). Hutton has nothing more to say about sensation, which is quite outside the range of his dissertation, and, as we saw above, he treats the nerve fluid as the controller of, but not the source of power for, muscular motion. Nutrition he thinks of as a process of accretion whereby liquid nutrients are transformed into solid matter, but the details of the process are obscure. "The proper matter of nutrition is not to be determined easily," he writes. "The transparent, thin, serous lymph which flows through all the points of the body, even the very smallest, is the most likely candidate for this role of nutrition-restoration. Can it be that the nerve juice forms truly solid parts" (XLII)? Because of its thickness, "the blood is found to be entirely unsuited for performing this task in the narrowest vessels" (XLII). And although he apparently believes the lymph bears most of the burden of nutrition (*cf.* XLV–XLVI), Hutton does not feel he can reach a clear conclusion on this question: "Now it is possible that they [i.e., all parts of the blood] all serve toward this purpose, at least instrumentally; and it is possible that nature makes use of not one particular animal fluid but two or more, according to its essential needs" (XLII). Turning then from the general process of nutrition to the way in which the supply of blood is replenished, Hutton provides a remarkably prescient description of cellular division: "And is not an increase or multiplication [in the quantity of blood] achieved through the accretion and completion of two parts of a particle of blood which has divided into two whole particles, which are similar to the original divided particle" (LXXIX)? Such are the hypotheses suggested by believing that every component of nature has its proper active power.

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[29] Hutton's account of displacement reactions is clearly derived from the equivalent weight studies of William Homberg and Andrew Plummer; see William Homberg, "Observation sur la Quantité d'Acides Absorbées par les Alcalis Terreus," *Mémoires de l'Académie Royal des Sciences,* 1700, pp. 64–71, and Andrew Plummer, "Experiments on Neutral Salts, compounded of different acid Liquors, and alcaline Salts, fixt and volatile, read 7 June 1739," *Essays and Observations, Physical and Literary* 1 (1754): pp. 315–340.

Hutton's theory of respiration appears to spring from a deep-rooted opposition to those earlier theories that attributed a vital spirit or *pneuma* to the air. "That air and blood should mix together in the lungs or have any direct contact is," he insists, "quite at variance with all reckoning and observation" (LXXV). But proper air and healthy respiration are undeniably necessary to life and Hutton therefore must explain why some airs support life while others do not. The explanation he provides focuses entirely on the mechanical elastic properties of air. "The effect which air, when it is broken up by combustion or sulfurous vapors, produces upon the respiration of animals has as its cause not the absence of vivifying breath but this air's very great unsuitability for distending the vesicles of the lungs" (XXXIX). To this negative argument he later adds a more constructive account of the role respiration plays in the animal economy. "The alternating activity of breathing in and breathing out" assists the blood in its passage through the lungs by thoroughly shaking up "the sticky items and the larger molecules" (LXXIV) and thereby helps the chyle become assimilated to the blood. This assimilation is further encouraged by the generation of heat in the lungs, "for when we see that there occur in the lungs a blending, a thorough shaking and a breakdown of diverse substances, as well as the tension and friction of blood globules and the elastic walls of the vessels, a great action necessarily follows therefrom, as well as a chemical and mechanical reaction; hence come the heat and those things which follow from it" (LXXVI). The air drawn into the lungs during respiration also serves to moderate the heat generated there through "the remarkable application of a colder medium" (LXXVI).

The closing pages of Hutton's dissertation are devoted to a discussion of diseases of the blood, their causes, and their treatment. Although this excursion into clinical medicine is buoyed up by a limited interest in theories of pathology, the result is more eclectic than systematic and appears to be a desultory response to the requirement that a medical dissertation actually make contact with medical practice. The diseases that afflict the blood can spring from an imbalance between the solids and the liquids in the body (LXXX–LXXXIII), from an acid-alkali imbalance in the blood (LXXXIII–LXXXIV), from a pollution (LXXXVII), from a weakness in the solid parts of the body (LXXXVIII), from a poison (LXXXIX) or from an infection (XC–XCI). These causes can act singly or in combination and give rise to so complex a situation that Hutton, in his attempt to order them, is even reduced to speaking of "animal humors" (XCI). But this concluding exercise in practical medicine clearly did not lie at the center of his thought, nor should we let it distract our attention from the chemical theories Hutton made central to his dissertation.

PART III—SOURCES

Being a composite rather than a synthetic treatise, Hutton's dissertation is made up of several loosely connected sections employing a wide range of concepts drawn from a variety of intellectual traditions. Eclecticism of this sort is hardly unusual in an inaugural dissertation, however, and offers certain advantages to the historian. Given Hutton's failure to identify his sources, in the dissertation at least we see his ideas presented in synoptic form rather than transformed through subordination to a single set of axioms. While we cannot identify with certainty the specific source of every discrete idea, several of the ongoing debates Hutton was engaging in are recognizable. We can thus locate his dissertation and its author in their appropriate doctrinal contexts, even though the available evidence does not enable us to reconstruct the sequence of his thoughts as he struggled to master his philosophical and scientific heritage.

A. The Chemical Philosophy

At the most general level Hutton's philosophy of nature can be identified as essentially chemical, but to do so invites misunderstanding. Modern chemistry, the science that traces its history back to Antoine Lavoisier and the chemical revolution of the late eighteenth century, conceives of itself as being above all an experimental science. Facts established through careful laboratory investigation are its foundation and point of departure; a logical ordering, both taxonomic and structural, of the substances studied is its first goal; a dynamic explanation of chemical change is its ultimate achievement. To some extent this characterization can be applied to Hutton's chemistry as well, but it fails to take account of a much larger set of assumptions and purposes central to his vision of chemistry. For Hutton, and for other participants in the tradition that Allen Debus has named "The Chemical Philosophy,"[30] chemistry begins with the conviction that nature is ordered in a certain way and that that order can best be known through certain kinds of investigation. Facts acquired by observation and experimentation can tell the investigator whether or not he has arrived at a proper understanding of his subjects, but they cannot speak for themselves or by themselves suggest new models of interpretation. For proponents of the chemical philosophy, as for modern chemists, agreement between fact and theory is the measure of the science's ability to explain natural phenomena, but their views on the temporal and logical relations between facts and theories are vastly different. Unless that difference is recognized, the historical value of seeing Hutton's philosophy of nature as essentially chemical will be utterly lost.

The chemical philosophy that evolved out of Renaissance naturalism and flourished well into the seventeenth century was characterized by certain distinctive assumptions that also are treated as fundamental in Hutton's dissertation. The notion that the universe is composed of two realms of order, the macrocosm of the nature that surrounds man and the microcosm of the human body, was central to the philosophy of Paracelsus and his more speculative heirs.[31] Opinions differed, of course, on how far this analogy should be pressed, on what linkages tie these two worlds of order together, and on the extent to which knowledge of these orders leads to knowledge of God. As we saw above, Hutton did little more than mention this analogy in his dissertation, but the concept was clearly one that gave added meaning to his study of the blood.

The belief that nature is built up from a multitude of closed cycles was another tenet of the chemical philosophy. This idea is also central to Aristotle's *Physics* and to the worldview of the mechanical philosophers of the seventeenth century, particularly those concerned with astronomical orbits, but in the chemical philosophy it was developed in certain distinctive ways. Many chemical philosophers believed that anatomical investigations of the human body reveal the structural foundations of microcosmic cycles in a way that could, through the analogy to the macrocosm, be made to illuminate the mystical anatomy of the universe. Chemists of this persuasion welcomed William Harvey's demonstration that the circulation is a closed cycle and sought to provide chemical explanations of the changes the blood undergoes and the functions it performs as it cycles through the body.[32] Thus for philosophical chemists and iatrochemists alike, the circulation of the blood provided a paradigm of the many cycles that take place in nature in general and, more particularly, in the fabric of the human body.

A belief that matter is active in the sense of being self-acting and self-sustaining was another basic idea of the chemical philosophy. While the history and implications of this concept are vast and complex, it essentially asserts that nature, having been created self-sufficient in its operations, in no way depends upon the intervention of a supernatural being.[33] The theory of matter embodying this belief attributes activity or power to fundamental matter itself. Thus for chemical philosophers the mechanical definition of matter in terms of mathematical quantities and passive substance is insufficient in that it fails to provide an adequate conceptual basis for the naturalistic explanation of natural phenomena. Chemists believed that the dynamic agents acting in nature must be located in nature itself.

If calling Hutton a chemical philosopher has the advantage of attaching his philosophy of nature to its ancestral intellectual tradition, it also raises a host of serious problems. In the first place it must be immediately granted that while many of Hutton's contemporaries admired his accomplishments as a chemist, their reports do not in general present him as a chemical philosopher in the sense in which we have been using the term here. To this one can only respond that while what it meant to be a chemist in the middle of the eighteenth century is not an easy matter to determine, for many it entailed acceptance of ideas and concepts that were as foreign to many chemists of the nineteenth century as they are today. But even if that point is granted one can still ask if there was a living tradition of chemical philosophy in Great Britain during the 1740s. Hadn't Newtonianism carried the day?

Study of the writings of Newton and his disciples has reached such a stage of refinement and has revealed such complexity that while we now know a great deal more about the subject, the central figure, at least as previously conceived, has dissolved before our very eyes. It is now realized that Newton's philosophy of nature was an attempt, brilliant but ultimately unsuccessful, to synthesize ideas drawn from a variety of traditions and that the eclecticism of theorists such as Hutton "is paralleled by Newton's own varying views on the nature of force." [34] Far from being a strict mechanist, Newton argued that there are active principles in nature driving nature in a perpetual circulation. He attempted to embody these principles in his concept of the aether, a concept that in his writings is unmistakably connected to older notions of chemical principles. It is thus now evident that "Newton's appeal to chemical principles as a key to unravel the fundamental problems of natural philosophy was a strong current in his thought, and suggests the continued influence of Paracelsian and Helmontian conceptions of a chemical philosophy of nature." [35]

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[30] Allen G. Debus, *The Chemical Philosophy*, (2 v. New York, 1977).

[31] Ibid., **1**: p. 205; for an indication of the centrality of the macrocosm-microcosm analogy to the chemical philosophy, see the many entries in Debus's index.

[32] Ibid., **2**: pp. 512–519; see also Audrey B. Davis, *Circulation Physiology and Medical Chemistry in England 1650–1680* (Lawrence, Kansas, 1973).

[33] *Cf.* Debus, n. 30, **2**: p. 346.

This recent recognition of the rich thematic complexity in Newton's works has in turn generated new interpretations of eighteenth-century natural philosophy, the challenge now being to describe the various schools of Newtonianism that emerged following the master's death.[36] Those who developed theories of active matter are seen as emphasizing the possibilities and implications of Newton's aether theory. But notice that this approach to the problem assumes that chemistry, insofar as it put forward a distinctive philosophy of nature, had been fully subsumed into the Newtonian tradition, as if to argue for active matter one had to begin with Newton's aether.[37] That Newton's concept of an aether gave rise to a wide range of influential commentaries, particularly after 1740, is beyond question, and certainly the authors of late eighteenth-century theories of active matter, such as the one Hutton put forward in the works he published towards the end of his life, were consciously responding to treatises written in this tradition, but it is also possible that these theorists were only incidentally concerned with the Newtonian aether. There is considerable evidence suggesting that while the Newtonians were attempting to incorporate certain chemical assumptions into their philosophies of nature, many chemists continued to champion the fundamental ideas of their science in their own distinctive ways. In Hutton's case it seems most likely that although while writing his dissertation he was aware of the debates among Newtonians, as any attentive student of Maclaurin's lectures would be, the independent tradition of chemical philosophy, and not the internal difficulties of Newton's concept of force, provided him with his basic assumptions, his tactics of investigation, and his strategy of interpretation. Certainly such a distinct chemical tradition was available to him.[38] According to this reading of the dissertation, Hutton should be seen as a chemical philosopher aware of Newtonian debates rather than as a Newtonian philosopher who happened to be a skillful chemist.

B. Scottish Philosophy

Biographical facts alone suggest that Hutton's understanding of the way one acquires knowledge of nature and the character and limits of that knowledge, that is, his philosophy of science, was gained during his student years in Edinburgh. Until his twenty-first year he lived as a youth and a student at the very center of the society and the particular institutions that gave birth to what came to be called the Scottish Enlightenment. He had the great advantage, from the student's point of view, of studying under early founders of that movement before their ideas had been codified by a school. The Scottish philosophy of "Common Sense," and the attacks and defenses it stimulated, belongs to the years following Hutton's departure for the Continent, and it would therefore be wrong to claim that the views on the nature of scientific reasoning he presents in the dissertation were influenced by that school or its opponents. But in a more general sense there was emerging in Scotland during the 1740s a distinctive approach to reasoning about nature, one that provided common ground for the lively intellectual debates that were to occupy the philosophers of Edinburgh during the latter half of the century.

Hutton came to maturity at a time when metaphysics was viewed in the Scottish capital as a worthy yet essentially unthreatening intellectual activity, but by the end of his life the reintroduction of political and religious controversy had again rendered speculation suspect. As Ramsay of Ochtertyre recalled in recollections written during the last quarter of the eighteenth century,

> It is well known that between 1723 and 1740, nothing was in more request with the Edinburgh *literati*, clerical and laical, than metaphysical disquisitions. These they regarded as more pleasant themes than either theological or political controversies, of which, by that time, people

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[34] Heimann and McGuire, n. 6, p. 302.

[35] Heimann, n. 6, pp. 8–10; *cf.* also Debus, n. 30, **2**: pp. 531–535 and B. J. T. Dobbs, *The Foundations of Newton's Alchemy* (Cambridge, 1975), chapter 6.

[36] *Cf.* Robert E. Schofield, "An Evolutionary Taxonomy of Eighteenth-Century Newtonianisms," in Roseann Runte, ed., *Studies in Eighteenth-Century Culture* 7 (Madison, Wisconsin, 1978): pp. 175–192.

[37] *Cf.* Heimann, n. 6, p. 9, where it is implied that Hutton came to believe in the circulation of the aether and the self-sufficiency of nature through his reading of Newton.

[38] See below, section III C; see also Allen G. Debus, "The Paracelsians in Eighteenth-Century France: A Renaissance Tradition in the Age of the Enlightenment," in *Transformation and Tradition in the Sciences* (I. B. Cohen Festschrift) (Cambridge, in press).

> were surfeited. The writings of Locke and Clarke, of Butler and Berkeley, presented a wide and interesting field of inquiry, in which they could exercise their intellectual powers without endangering their own quiet or safety. By treading in the steps of men who were able and eloquent champions of revealed religion, there was little danger of alarming the orthodox clergy, whose scruples and jealousies were at that time carried sufficiently far.[39]

The point made concerning the orthodoxy of men such as Locke and Berkeley is a valuable reminder that their frequently skeptical comments on the nature of knowledge were not always taken as attacks on the established church or its beliefs. Ramsay elsewhere comments that the Rankenians, members of an Edinburgh philosophic club organized in 1716 or 1717, "explored the mazes of metaphysics with ardour tempered by caution," a phrase that could be used to describe Hutton's speculative manner as well.[40]

In social terms, metaphysical speculation, by providing a suitable mode of discourse for the construction of an essentially secular culture, served as a philosophical complement to economic improvement and polite literature. For the professors in the university, however, speculation about the mind and our knowledge of natural phenomena had a direct bearing on the way they conducted their investigations and organized their professional lives. Unlike the jurists, wealthy merchants, and aristocratic gentry who enlarged and decorated their cultural activities with metaphysics, the professors worried about its impact on their professional conduct and organized societies that would serve their distinctive needs as well. Thus during the 1730s were founded the Edinburgh Medical Society, under the leadership of the anatomist, Alexander Monro; a student medical society, which later became the Royal Medical Society; and, towards the end of the decade, the Philosophical Society, led by Colin Maclaurin.[41] Hutton could hardly have been unaware of these societies and the pressures to which they responded during his student years and he well may have been a member of the student medical society. In them and in the university he was attending he saw science emerging as a profession that combined philosophical reflection, a concern with if not a direct involvement in economic improvement, and an attention to the felicity of expression and sociability needed to sustain social institutions serving a variety of interests. We know that when Hutton settled in Edinburgh in 1768 he joined the Philosophical Society and that a few years later he was a very active member of its direct descendant, the Royal Society of Edinburgh. To understand why Hutton was both intellectually and socially attuned to the Scottish Enlightenment, we need look no further than the character of the learned world he lived in during his early years in Edinburgh.

Both Maclaurin and Stevenson, the teachers who made the most lasting impressions on Hutton, were prominent figures in the cultural life of Edinburgh. In addition to being Great Britain's most eminent mathematician and Edinburgh's most distinguished professor, Maclaurin was "a man of remarkable social qualities, . . . a prominent figure in all the scientific circles of Edinburgh in those days, . . . [and] the life and soul of the University of Edinburgh." [42] He was, with Stevenson, a member of the Rankenian Club, where he doubtless discussed Berkeley's attacks on the calculus that he later refuted in his *Treatise on Fluxions*.[43] Active in both the Medical Society and the Philosophical Society, Maclaurin exemplified both professional competence and social leadership during the period in which natural philosophy was established as a central component of the Scottish Enlightenment.

John Stevenson is remembered for revitalizing the study of logic and metaphysics in the University of Edinburgh. "The most popular of all the Professors on account of his civility and even kindness to his students," [44] he set aside the texts of Aristotle and Ramus in favor of books on logic by Dutch professors and an abridgement of Locke's *Essay Concerning Human Understanding*.[45] He also encouraged his students to read Berkeley's works and made criticism of his doctrine of immaterialism a central issue in his class. But even more novel was Stevenson's inclusion of rhetoric in his course and his emphasis on criticism and *belle lettres*. He was, Ramsay of Ochtertyre recalled, "one of the first professors in Scotland who called the attention of their pupils to matters of taste, and connected the compositions of Greece and Rome with those of modern times." Indeed, it was even alleged "that by setting young men's heads agog with the lighter parts of literature, he diverted their attention from branches of science which, though seemingly dry and uninteresting in the first stages of them, are indispensable in the learned professions." [46] Certainly this was not the case with Hutton, who may well have acquired his taste for metaphysics, in addition to discovering his powerful attraction to chemistry, while attending Stevenson's lectures.

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[39] Alexander Allardyce, ed., *Scotland and Scotsmen in the Eighteenth Century, from the MSS. of John Ramsay, Esq. of Ochtertyre,* (2 v., Edinburgh, 1888), **1**: pp. 195–196.

[40] Ibid., **1**: p. 9. On the Rankenians, see Ernest C. Mossner, *The Life of David Hume* (Austin, Texas, 1954), pp. 48–49.

[41] See John Christie, "The Origins and Development of the Scottish Scientific Community, 1680–1760," *History of Science* **12** (1974): pp. 122–141, pp. 132–134; Roger L. Emerson, "The Philosophical Society of Edinburgh, 1737–1747," *The British Journal for the History of Science* **12** (1979): pp. 154–191.

[42] Alexander Grant, *The Story of the University of Edinburgh During its First Three Hundred Years,* (2 v. London, 1884), **2**: p. 299.

[43] Edinburgh, 1742. *Cf.* Mossner, n. 40, p. 48.

[44] Alexander Carlyle, *Autobiography,* 2nd ed. (London, 1860), p. 42.

[45] Grant, n. 42, **2**: p. 328, and William S. Howell, *Eighteenth-Century British Logic and Rhetoric* (Princeton, 1971), pp. 272–273.

[46] Allardyce, n. 39, **1**: pp. 232–233.

Several key features of Hutton's philosophy of science can also be traced back to Scottish philosophy as it existed in the 1740s. On the critical side, Berkeley's Scottish heirs responded to his attacks on seventeenth-century philosophy by reading Newton in a very cautious manner. Hume's statement on this matter, while well-known, bears repeating: "While Newton seemed to draw off the veil from some of the mysteries of nature, he shewed at the same time the imperfections of the mechanical philosophy, and thereby restored her ultimate secrets to that obscurity in which they ever did and ever will remain." [47] While unwilling to surrender the possibility of fathoming the inner secrets of nature, Maclaurin, in his *Account of Sir Isaac Newton's Philosophical Discoveries*, also refused to claim more for Newton than could be strictly defended. "It is not the business of philosophy, in our present situation in the universe," he said,

> to attempt to take in at once, in one view, the whole scheme of nature, but to extend, with great care and circumspection, our knowledge, by just steps, from sensible things, as far as our observations or reasonings from them will carry us, in our enquiries concerning either the greater motions and operations of nature, or her more subtile and hidden works. In this way Sir Isaac Newton proceeded in his discoveries.[48]

Such caution had the effect of minimizing the claims made for Newtonianism as a philosophy of nature while emphasizing its value as a model of scientific investigation. But the model did not carry with it the implication that either the mechanical notion of inert matter and active forces or the mathematical description of nature were privileged concepts. As one Edinburgh-trained doctor wrote in the early nineteenth century,

> The labours of Colin Maclaurin, . . . by explaining the true and legitimate application of the researchers of Newton, ought to have satisfied all sound thinkers, that medicine was not the field for the application of geometry, and that, however useful when applied to mechanics and physics, the application of mathematical reasoning to elucidate the actions of animal bodies is barren and unprofitable.[49]

Hutton must have found such a reading of Newton liberating. On the one hand it freed him from the methodological assertion, embodied in Newton's Third Rule of Philosophizing, that one could argue by analogy from the properties of sensible bodies to the qualities of the ultimate particles of nature.[50] One welcome consequence of this denial that a theory of matter could be formulated from which all natural phenomena could be deduced was the enhanced philosophical standing of non-mechanical and non-mathematical sciences such as chemistry and medicine. Thus Hutton could be both a Newtonian, in the attenuated Scottish methodological sense, and a philosophical chemist.[51] As he read in the chemical literature published in the 1730s and 1740s, Hutton must have noticed the growing independence of writers like Peter Shaw who, having adhered closely to Newton's program for natural philosophy until the master's death in 1727, soon after began arguing with increasing conviction for a conceptually distinct science of chemistry. As Shaw and others soon discovered, the teachings of the eminent German chemist G. E. Stahl provided powerful arguments in support of such a view.

In 1730 Shaw published a translation of Stahl's system under the title *Philosophical Principles of Universal Chemistry*.[52] In this work Stahl argued that chemistry must be theoretically independent because the phenomena it seeks to explain are of a different order of complexity from those studied by natural philosophers. Explanations which begin with statements about the primary particles of matter may meet the needs of physicists, but chemistry deals with qualities of matter that are too various and too specific to yield to the general assumptions of natural philosophy. The successes of the mechanical philosophy were obviously impressive and a sufficient justification for this approach to physics. Nevertheless, natural philosophers should not claim that their branch of science provides a system of concepts that is adequate for all branches of science. Stahl argued that chemists must identify a set of principles having enduring chemical properties, even though they know that these principles are probably compounded out of smaller physical particles of matter. Acidity, alkalinity, inflammability, and metallicity are real properties, and chemists are responsible for creating theories that can account for the distinctive and specific characteristics of these properties. While such theories should not contradict the established theories of natural philosophy, their acceptability depends primarily upon their ability to explain chemical phenomena. This was an argument Hutton must have found most congenial.[53]

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[47] David Hume, *History of England,* chapter 71, as quoted in Norman Kemp Smith, *The Philosophy of David Hume* (London, 1941), p. 58.

[48] Colin Maclaurin, *An Accountant of Sir Isaac Newton's Philosophical Discoveries* (London, 1748), p. 19.

[49] John Thomson, *An Account of the Life, Letters, and Writings of William Cullen,* (2 v. Edinburgh, 1859), **2**: p. 678.

[50] *Cf.* Heimann and McGuire, n. 6, pp. 245–246; J. E. McGuire, "Atoms and the 'Analogy of Nature': Newton's Third Rule of Philosophizing," *Studies in History and Philosophy of Science* **1** (1970): pp. 3–58.

[51] For an account of a later and more skeptical formulation of Scottish methodological Newtonianism, see L. L. Lauden, "Thomas Reid and the Newtonian Turn of British Methodological Thought," in R. E. Butts and J. W. Davis eds., *The Methodological Heritage of Newton* (Toronto, 1970).

[52] London.

Those eager to revitalize the science of chemistry naturally employed the reigning methods of scientific investigation and theory construction, methods that Hutton made central to his dissertation. Like other chemists he faced a two-fold task. On the one hand he had to break down the substances studied by chemists into their chemical constituents and then sort these "simples" into appropriate categories. Logically, this involved analysis, abstraction, and classification. On the other hand he had to characterize chemical changes and say why they occurred, a task that required description, abstraction, explanation and, if he chose to go further, generalization. The way Hutton fulfilled these requirements was in no way original, but the choices he made do reveal something of his thought. He was a great believer in the power of the human mind and insisted that while all knowledge must begin with sensation, the mind can reason with assurance to a level of knowledge not conveyed by the senses.[54] When proceeding taxonomically, chemical analysis at the laboratory bench isolates constituents that can then be grouped according to certain key properties, such as solubility in water, resistance to fire and so forth. These properties are then in the abstract taken as the defining properties of the chemical principles, which become the primary categories for the classification of simple chemical substances. Dynamically, certain chemical changes, such as acid-alkali neutralization or displacement in a solution, are taken as paradigmatic of particular types of chemical changes. The theorist's task is to identify by abstraction the relevant properties of the active constituents, explain how those properties bring about the changes observed, and finally state the covering law of which the case examined is an instance.

When constructing dynamic explanations, Hutton followed Locke in attributing powers to chemical constituents.[55] To avoid an unlimited multiplication of powers, he argued analogically whenever possible. Thus in explaining how air can be fixed in the blood he suggests that the forces it exhibits depend on the disposition of its particles, as is the case in bodies that can be electrified (XXXVIII). The active powers of substances, which now add a causal component to principles that were originally identified for taxonomic purposes, are then used to explain the changes observed. Thus neutralization is the result of the interaction of the acid and alkali powers (XXVII). Naturally this is not the end of the story, for Hutton would like to generalize such an explanation into a more comprehensive statement about attraction and repulsion, but such general laws are not easily discovered. The one general law of this sort that he does hazard in the dissertation asserts that in displacement reactions the simpler substance always displaces the more complex (XXVII).

C. Chemistry at Mid-Century

Ever since Antoine Lavoisier announced his revolution in chemistry, the last two decades of the eighteenth century have been considered the well-spring of modern chemistry. But Lavoisier's revolution built upon an earlier revolution in which chemistry was reestablished as a separate and distinct science no longer subordinated to the corpuscular or mechanical conception of nature. Of course chemistry, like nations which attain political independence, was not entirely the creation of the revolution by which it achieved autonomy, but its change of status, as reflected both in the way it was defined and in its place in the larger world of natural philosophy, was noteworthy. One reason Hutton found this revitalized science so fascinating, I suspect, was that he encountered it at just the historical moment when chemistry seemed uniquely capable of engaging precisely those problems of the activity and self-sufficiency of nature that could not be adequately explained, at least in naturalistic terms, by the then dominant philosophies of nature. But to understand how during the second quarter of the eighteenth century chemists could entertain such hopes, we must first look briefly at the chemical theories of the immediately preceding period.

The foremost textbook in chemistry between its first publication in 1675 and the middle of the eighteenth century was Nicholas Lemery's *Cours de Chymie*.[56] While primarily a descriptive work, Lemery's text explains several chemical reactions, such as the dissolution of metals in acids, in terms of a corpuscular theory drawn from the philosophies of Descartes and Gassendi. Chemical substances are assumed to possess pores and spikes of certain sizes, physical attributes which explain why and how they react. But by the time Hutton began studying chemistry this hypothesis no longer commanded much respect and hence he could dismiss with a mere mention "spiculae and pores, . . . sword and sheath" (XXVII).

Among Newtonian natural philosophers the subordination of chemistry to the mechanical tradition was, as indicated above, a much more complex affair.[57] Within the Newtonian circle in London the debate focused on the question of whether attractive forces alone act in nature or whether repulsive forces are also present. This particular debate was effectively resolved in 1727, the year of Newton's death, with the publication of Stephen Hales's *Vegetable Staticks*,[58] in which a brilliant experimental study of the chemical fixation and release of air is used to sustain an argument for the presence of repulsive forces in nature. The Newtonian conviction that explaining natural phenomena consists of accounting for appearances in terms of inert matter and attractive and repulsive forces was then challenged by those who, using Locke's terminology, believed matter to be active and forces to be manifestations of the powers of matter.[59] By the time Hutton began the study of chemistry the concepts of active matter and natural powers were widespread and, as we have seen above, he found them particularly congenial to his philosophy of nature. But the Newtonian use of these ideas had left its mark. Hutton, like his contemporaries, was cautious in the attribution of powers, not, so far as we can tell, because he feared the ridicule heaped on Molière's physician, who attributed the efficacy of a sleeping potion to its dormative power, but because behind the eighteenth-century notion of powers lay the awesome Newtonian conception of a nature subject to the titanic opposition of attractive and repulsive forces. Thus while British chemists learned to live without Newtonian atoms, elements and forces, they continued to believe that the dynamic constituents in nature, its powers, are of two basic sorts, the attractive and the repulsive.

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[53] On Shaw and Stahlian chemistry in Great Britain, see F. W. Gibbs, "Peter Shaw and the Revival of Chemistry," *Annals of Science* **7** (1951): pp. 211-237, and Donovan, n. 17, pp. 30-32.

[54] Heimann and McGuire, n. 6, pp. 267-268.

[55] On the Lockean notion of powers, see ibid., pp. 246-251, and Donovan, n. 17, pp. 43-44; *cf.* also P. M. Heimann, "Voluntarism and Immanence: Conceptions of Nature in Eighteenth-Century Thought," *Journal of the History of Ideas* **39** (1978): pp. 271-283, pp. 277-279.

[56] Paris. For bibliographical details and a précis of the text, see J. R. Partington, *A History of Chemistry,* (4 v., London, 1961-1970), **3**: pp. 28-41.

Discussions of chemical principles provide another indicator of the status of chemistry within natural philosophy. The analysis of chemical substances into their principles, and the attribution of essential properties to such constituents, goes back to at least the *tria prima* (salt, sulfur, and mercury) of Paracelsus, while the supposition that there are five principles was put forward early in the seventeenth century.[60] By the end of the seventeenth century, however, the relationship between descriptions of elementary matter advanced by corpuscularian and mechanical philosophers and the principles identified by chemists had become thoroughly muddled. Those who rejected Lemery's notion that the characteristics of chemical substances depend solely on their surface geometry had to decide which properties of the chemical principles were derived from their physical properties and which from their distinctive chemical properties. Natural philosophy could not harbor two different theories of matter, and systems of chemical principles, if they were to be anything more than taxonomic schemes, had to be defined in relation to the atoms and physical elements of the mechanical philosophers.

Constructing a consistent theory of chemical principles and physical elements was not a task that the great teacher Hermann Boerhaave was willing to take on. In his chemical lectures at Leiden, and in the text compiled from them, he sought only to introduce his students to chemistry, not to reduce its theory to logical order. As he wrote in a prefatory note, "the author's aim is not to improve the matter, but only the manner of the science: that is, to dispose the materials of it in a more natural and more useful order, than had been done before." [61] His discussion of chemical substances is entirely taxonomic, being in fact a natural history, the claim that the principles are in some sense simple substances receiving no encouragement.[62] The truly elementary substances according to Boerhaave are fire, air, water, and earth, and he presents them not as chemical principles but as instruments of chemistry.[63] Chemists employ the properties of these instruments when analyzing natural substances, this being their chief contribution to natural philosophy.[64] But such an approach runs into problems when one asks, for instance, if fire enters into combination with bodies or is merely a name for the release of heat. When faced with this problem Boerhaave multiplied entities, speaking on the one hand of the *materia ignis* that combines with metals during calcination and, on the other, of the *pabulum ignis* which is the fuel of fire in combustion. Such eclecticism provided a poor model for chemists eager to formulate comprehensive new thories for their science.[65]

G. F. Rouelle, whose popular chemistry lectures

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[57] Arnold Thackray, *Atoms and Powers* (Cambridge, Mass. 1970), chapters 1–4.

[58] London.

[59] See above, section III B. For a lively account of the links between post-Revolutionary political-theological debates and the various theories of matter advanced by natural philosophers, see Margaret Jacob, *The Newtonians and the English Revolution 1689–1720* (Ithaca, N.Y., 1976), pp. 234–238 and passim.

[60] The earliest use of five chemical principles, by Joseph Duchesne, is described in R. Hooykaas, "Die Elementenlehre der Iatrochemiker," *Janus* **41** (1937): pp. 26–28. Lemery used a system of five principles but denied that they can explain chemical change; see Maurice Crosland, *Historical Studies in the Language of Chemistry* (London, 1962), p. 62.

[61] Hermann Boerhaave, *A New Method of Chemistry*, trans. and notes by Peter Shaw, (2 v., 2nd ed., London, 1741), "The Author to the Reader."

[62] Ibid. **1**: pp. 65–155.

[63] Ibid. **1**: pp. 205–488.

[64] Ibid. **1**: pp. 172–173.

[65] For a précis of Boerhaave's two-fluid theory of fire, see Rhoda Rappaport, "Rouelle and Stahl—The Philogistic Revolution in France," in Henry M. Leicester, ed., *Chymia* **7** (Philadelphia, 1961): pp. 73–102, pp. 91–92. Rappaport (pp. 88–90) also cites with approval F. W. Gibbs's thesis that while "Boerhaave was considered the guiding spirit in the laboratory, . . . Stahl was, at the very same time, the great figure in systematic or 'sublime and philosophical' chemistry."

Hutton may have attended when he was studying in Paris, modified the element/instrument theory of Stahl, which was essentially the same as Boerhaave's, so as to emphasize its chemical content.[66] Rouelle taught that "all chemical reactions can in fact be explained in terms of the chemical and mechanical behavior of the four elements," these being fire, air, water, and earth. "Each of the elements has, for Rouelle, a dual nature; each serves as both a component of matter and an instrument of chemical reaction." [67] The details of this system need not detain us, for they in no way illuminate the specific content of Hutton's dissertation, but the general problem of reconciling the constitutive and the instrumental features of these "elemental" substances merits attention. Hutton treaded gingerly when traversing this conceptual mine field. In his system of five principles water, air, and sulfur-as-a-source-of-heat-and-fire are considered elementary instruments as well as constituent substances whereas sulfur-as-the-matter-of-fire-and-light, salt, and earth are considered purely chemical principles. Far from marking a clear step towards the resolution of this thorny set of problems, Hutton's discussion merely tells us that like his contemporaries, he too labored under the conceptual difficulties involved in creating a truly independent chemical theory of matter.[68]

Throughout the eighteenth century the chemical principles were considered hypothetical and tentative when compared to the confident descriptions of elementary matter provided by physicists, a relative evaluation that was not finally abandoned until the acceptance of Dalton's atomic theory. But there were two strategies that enabled one to avoid this embarrassing comparison. One could argue from a critical point of view that the mechanical philosophers, whatever their claims, knew nothing about the true nature of elementary matter, such facts being quite simply unattainable. This, as we have seen, was Hume's approach and soon became a commonplace in Scottish philosophy. Or one could say that whatever natural philosophers may claim to know about the elements, chemists have their own approach to the identification of elementary substances, an approach that has the advantage of bringing order to the many intermediate steps involved in this task. This was the position taken by G. E. Stahl, and while his followers in Great Britain and France largely rejected his specific system of chemical principles, they found his hierarchical notion of compounding a valuable concept. If chemistry experienced a revolution during the second quarter of the eighteenth century, one that elevated it to the level of an independent science, then the crucial role played by this doctrine deserves to be recognized.[69]

Stahl taught that "all *natural Bodies* are either *simple* or *compounded*; . . . The *simple* are *Principles*, or the first material causes of *Mixts*; and the *compounded*, according to the difference of their mixture, are either *mix'd, compound* or *aggregate: mix'd*, if composed merely of Principles; *compound*, if form'd of Mixts into any determinable single thing; and *aggregate*, when several such things form any other entire parcel of matter, whatsoever it be." [70] The advantages of such a view were twofold. On the one hand it allowed one to continue believing that chemical analysis and the mental act of abstraction will eventually lead to the recognition of the true elementary principles, while on the other it provided a terminology for describing the intermediate steps taken in analysis. Stahl believed that the search for chemical principles had been confused by "a neglect of that real distinction between original and secondary mixts, or mixts consisting of principles and bodies compounded of mixts," and he taught that "by justly distinguishing between mixts and compounds, without directly undertaking to exhibit the first principles of the latter, we may easily settle this affair." [71] This doctrine, which gave chemists hope, in the sense of asserting the philosophic worth of their enterprise while legitimizing the analytic procedures that were their main occupation, was eagerly adopted during the second quarter of the eighteenth century. In Great Britain Peter Shaw made Stahl's ideas increasingly central to the commentaries and lectures he published after translating Stahl's system into English. In France Rouelle emphasized Stahl's doctrine of mixts and compounds, and Hutton may well have been encouraged by his example to use it himself. In any case, Hutton evidently had Stahl's hierarchial doctrine in mind when he said that in the blood the "principles have not been merely blended together, united, and combined but these greater and lesser combinations are also joined, thoroughly blended, and remarkably well combined" (XV). Such a doctrine, when combined with Scottish skepticism about the possibility of knowing the real properties of elementary matter, made chemistry appear a rather reasonable approach to the study of nature.

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[66] *Cf.* David Oldroyd, "An Examination of G. E. Stahl's Philosophical Principles of Universal Chemistry," *Ambix* **20** (1973): pp. 36–52, pp. 48–49.

[67] Rappaport, n. 65, p. 76. For biographical information on Rouelle, see Rhoda Rappaport, "G.-F. Rouelle: An Eighteenth-Century Chemist and Teacher," in Henry M. Leicester, ed., *Chymia* **6** (Philadelphia, 1960): pp. 68–101.

[68] For Joseph Black's later rejection of the whole notion of instruments of chemistry, see his *Lectures on the Elements of Chemistry*, John Robison, ed., (2 v., Edinburgh, 1803), **1**: pp. 286–287.

[69] For Great Britain, see Gibbs, n. 53, and Donovan, n. 17, chapters 2–6; for France, see Rappaport, n. 65, and Martin Fichman, "French Stahlism and Chemical Studies of Air, 1750–1770," *Ambix* **18** (1971): pp. 94–122. In Great Britain during the 1730s and 1740s, the concept of phlogiston, which Lavoisier later made the whipping boy of the old chemistry, played no part in the Stahlian revival—the term is not even mentioned in Shaw's 1730 translation of Stahl; see Thackray, n. 57, p. 119. While Rouelle did use the concept, it was not an organizing principle in his system: "Phlogiston is not presented as the center and focus of Rouelle's chemical theory. In fact, there is no single place in his chemical lectures where the reader can find a statement of all the major points of the phlogistic doctrine;" Rappaport, n. 65, p. 77.

[70] Stahl, n. 52, p. 3. For a brief account of Stahl's chemistry, see Thackray, n. 57, pp. 171–176.

[71] Stahl, n. 52, pp. 4–5.

A closer look at certain features of Hutton's dissertation reveals that his chemical system combines ideas drawn from the British Newtonian tradition and from the tradition of medical chemistry. We have practically no direct information as to which chemical authors Hutton took as his guides and the information we do have, which is provided by Playfair, seems suspicious if not irrelevant. According to Playfair, as soon as Hutton's curiosity had been aroused by Stevenson's allusion to the action of *aqua regia,*

> he made an immediate search for books that might give him some farther instruction concerning the fact which he had just heard of; but the only one he could procure, for a long time, was Harris' *Lexicon Technicum,* the predecessor of those voluminous compilations which have since contributed so much more to extend the surface, than to increase the solidity of science. It was from the imperfect sketch contained in that dictionary, that he derived his first knowledge of chemistry. . . .[72]

We have no grounds for questioning the accuracy of this report but neither should we attach too much significance to it. Playfair's denigration of dictionaries and encyclopedia is ironic, given his later contribution to the *Encyclopedia Britannica,*[73] and raises the suspicion that by listing Harris's work as Hutton's primary source he may have intended to imply that Hutton's attachment to chemistry owed little to the deeper philosophical and methodological concerns we have been examining. But whatever use Hutton made of Harris's compilation, it seems highly unlikely that he turned to it for theoretical guidance. Certainly he did not there find the set of five principles he made central to his own chemical theory.

According to Hutton, the five principles are salt, water, sulfur, earth, and air (XIII). Harris also lists five principles, his being salt, phlegm, oil, earth, and spirit.[74] Spirit he further identifies as mercury[75] and salt he claims, following Newton, is a compound of earth and acid.[76] His omission of air from the list of principles is hardly surprising since it only came to be considered as such following the publication of Hales's *Vegetable Staticks,* but it provides yet another indication that we must look beyond Harris's *Lexicon* for the sources of Hutton's theoretical ideas.

The element/instrument theories of Boerhaave, Rouelle, and Shaw clearly had as little influence on Hutton's choice of principles as did Stahl's Becherian theory of water and three types of earth.[77] But if we turn to Hales, who is not normally thought of as a chemical theorist, we will find Hutton's principles listed under exactly the same names used in the dissertation. The main burden of Hales's argument is well-known—he believed air is composed of particles that have the distinguishing property of possessing a repulsive force when free, this force, and the elasticity it causes, being lost when air is fixed in liquids or solids. Air, he argued, "is very instrumental in the production and growth of animals and vegetables" and when fixed in them contributes greatly "to the union and firm connection of the several constituent parts of those bodies, *viz.* their water, salt, sulphur and earth."[78] That his argument is primarily directed towards theoretical chemists becomes clear when he concludes that air has as good a claim to being considered a principle as have water, salt, sulfur, and earth: "May we not with good reason adopt this now fixt, now volatile *Proteus* among the chymical principles, and that a very active one, as well as acid sulphur; notwithstanding it has hitherto been overlooked and rejected by Chymists, as no way intitled to that denomination?"[79] Hutton, like Shaw, Boerhaave, and Rouelle, accepted Hales's argument and included air in his list of principles, but he went further than they did in also accepting Hales's identification of the other principles as well.[80]

To understand Hales's larger purpose in urging the inclusion of air among the chemical principles, and to help explain Hutton's use of his conclusions, we must briefly review the Newtonian program for chemistry. Stated in its starkest terms, Newton and his followers were trying to subordinate the acid-alkali theory of chemical action to the mechanical theory of forces. Consider, for instance, Newton's own "Some Thoughts about the Nature of Acids" published in Harris's *Lexicon Technicum.*[81] He begins by asserting that "the Particles of Acids are of a Size grosser than those of Water, and therefore less volatile; but much smaller than those of Earth, and therefore much less fix'd than they. They are endued with a great Attractive Force; in which Force their Activity consists. . . ." [82] Since Newton's purpose is to explain all natural phenomena in terms of attractive forces and inert matter, he must argue that the alkalis, which chemists consider distinct active substances, are derived from the attractive acids: "The Particles of *Sal Alkali*, do consist of *Earthy* and *Acid* united together. . . ." [83] Other apparently distinct substances also owe their activity to the attractive power of the acids, such as the "Acid that lies suppress'd in sulphureous Bodies. . . ." [84] Thus all substances, including those whose properties were previously explained in terms of the acid-alkali theory, can be seen as composed of inactive matter and attractive acid particles: "All Bodies have Particles which do mutually attract one another: The Summs of the least of which may be called Particles of the *first Composition*, and the Collections or Aggregates arising from the, Primary Summs; or the Summs of these Summs may be call'd Particles of the *second Composition, &c.*" [85]

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[72] Playfair, n. 13, p. 40.

[73] John Playfair, "A General View of the Progress of Mathematical and Physical Science Since the Revival of Letters in Europe," *Encyclopedia Britannica,* supplement (Edinburgh, 1816), **2, 4.**

[74] John Harris, *Lexicon Technicum: or, an Universal English Dictionary of Arts and Sciences* **1** (London, 1704); **2** (London, 1710), **1,** "Principle".

[75] Ibid., 1, "Spirit."

[76] Ibid., 2, "Salt."

[77] For Shaw's views on the chemical principles, see Gibbs, n. 53, p. 221.

[78] Hales, n. 58, p. 314.

[79] Ibid., p. 316.

[80] On Shaw's acceptance of air as a principle, see Thackray, n. 57, p. 116; on Boerhaave and air, see Milton Kerker, "Hermann Boerhaave and the Development of Pneumatic Chemistry," *Isis* **46** (1955): pp. 36–49; on Hales's influence on Rouelle, see Henry Guerlac, "Lavoisier and His Biographers," *Isis* **45** (1954): pp. 51–62.

[81] Harris, n. 74, **2**: fasc. repr. in I. B. Cohen, ed., *Isaac Newton's Papers & Letters On Natural Philosophy,* 2nd ed. (Cambridge, Mass., 1978), pp. 256–258. Newton wrote this essay for the Scottish iatromechanician and teacher of Boer-

Hales's contribution was to add a second force, the repulsive force of air, to this theoretical program. This addition enabled him to explain certain phenomena in terms of the interaction of the attractive and repulsive forces. Newton, for example, favored a kinetic theory of fire whereas Hales provided a reactice account: "Fire is chiefly invigorated by the action and re-action of the acid sulphureous particles of the fuel, and the elastic ones which arise and enter the Fire, either from the fuel in which they abound, or from the circumambient air." [86] Thus fire becomes a compound which, when fixed like air in bodies, can, depending on the proportion of repulsive to attractive particles, endow them with alkaline or acidic properties. In one sense then, Hales refashioned the force theory of Newtonianism so that it more closely resembled the older acid-alkali theory of the chemists.[87] To revive that theory, and free it from subordination to mechanics, one only needed to dissolve the hypothetical particles into chemically defined substances and redefine the hypothetical attractive and repulsive forces as the observable powers of those substances.

Hutton's dissertation records his thinking as he struggled to thread his way through these conceptual thickets. He has largely dispensed with particles and forces. The sulfur principle contains "the matter of fire and light" (XXXI) and acidity is once again seen as the essential property of the salt principle (XXIV–XXVI). He also wants to treat earth as an active principle rather than as an inert substance and therefore focuses on its affinity for the saline principle. When combined with acidic salt, earth becomes alkaline, thereby providing the foundation for further explanation in terms of acid-alkali interactions. The other two principles, air and water, are active in the sense of causing changes, the one by its mechanical elasticity and the other by its power to dissolve bodies, but neither has distinctive chemical properties. Thus while Hutton accepted Hales's identification of air as a principle, it was much less significant in his system than it was for Hales. Looking ahead, we can also see that for Hutton it possessed none of the chemical significance attributed to the airs by pneumatic chemists during the latter half of the eighteenth century. It is also worth noting that for Hutton, as for British chemists in general at mid-century, phlogiston had not yet made its appearance as an organizing concept in chemical theory.[88]

D. Medical Theories

When viewed from the vantage point of the history of medicine, Hutton's dissertation can be seen as a late development of two interpretive themes, the first being the circulatory approach to physiology and its associated so-called "chemical anatomy" of bodily fluids, the second being the theoretical debate between the iatrochemists and the iatromechanicians.[89] Medical theorists had long studied the blood, but during the seventeenth century, following William Harvey's demonstration that the blood circulates throughout the body, the humoral doctrines used by classical theorists to explain its properties were largely displaced by chemical doctrines. Anatomy being the analytical branch of medicine, the analysis of blood was given the name chemical anatomy, a mode of investigation that could also be applied to the study of

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haave, Archibald Pitcairn; on Pitcairn, see Lester King, *The Philosophy of Medicine* (Cambridge, Mass., 1978), pp. 109–118.

[82] Cohen, n. 81, p. 257.

[83] Ibid.

[84] Ibid., p. 258.

[85] Ibid. Newton's statement on the formation of complex molecules from simple atoms appears at first glance to resemble Stahl's doctrine of mixts, and indeed early commentators considered their views of nature compatible; *cf.* J. B. Senac, *Nouveau Cours de Chymie suivant les principes de Newton et de Stahll* (Paris, 1723). But the reductionist thrust of Newton's chemistry, a consequence of his belief that the real properties of atomic matter are fundamental causes that can be known, was consistently opposed by Stahlian chemists after 1730.

[86] Hales, n. 58, p. 279.

[87] *Cf.* Hales's account of the causticity of quicklime: "From this manifest attraction, action and reaction, that there is between the acid, sulphureous and elastick aereal particles, we may not unreasonably conclude, that what we call the fire particles in Lime, and several other bodies, which have undergone the fire, are the sulphureous and elastick particles of the fire fixt in the Lime," ibid., p. 285.

[88] See above, n. 69.

[89] See Davis, n. 32, especially pp. 215–219, and King, n. 81, chapters 4–5.

other bodily fluids, such as urine. In moving from analysis to explanation, the circulation physiologists of the late seventeenth century relied primarily on the chemical doctrines developed by chemical philosophers interested in applying their theories to the study of medicine. But these iatrochemical ideas were challenged during the late seventeenth and early eighteenth centuries by the mechanistic doctrines of the iatromechanicians. The differences between these two theoretical stances were real, although both sought to explain the same bodily functions, and yet by the time Hutton began his study of medicine the heroic stage of their confrontation had passed, electicism and compromise having become more common.

Hutton studied medicine in Edinburgh during the final years in which the pure Boerhaavian doctrines of the medical school in Leiden, upon which the Edinburgh school was modeled, reigned unchallenged.[90] The modern medical faculty founded in Edinburgh in 1726 consisted of five professors, all of whom had studied under Boerhaave in Leiden. Andrew St. Clair, professor of the institutes of medicine from 1726 until 1747, the year Hutton left for the Continent, remained a faithful disciple. He taught physiology and general pathology by presenting a series of commentaries on Boerhaave's *Institutes of Medicine* that provided the full text of his master's lectures on these subjects. His colleagues were equally devoted Boerhaavians, so that when Hutton was attending lectures in the medical school, "Boerhaave's theory of medicine was the only one with any credibility at Edinburgh." [91]

It is hardly surprising, therefore, to find that in his accounts of the major physiological systems Hutton adheres closely to the Boerhaavian line. Essentially an iatromechanician, Boerhaave accepted the physiological primacy of circulatory systems and the need to analyze bodily fluids while employing a Newtonian theory of inert particles and active forces to explain how the Cartesian man-machine functions.[92] In doing so, he sought to accommodate as many ancient and modern doctrines as could by redefinition be included within his highly elastic conception of rational explanation. For instance, when applying his physiology to the problem of disease, Boerhaave conformed to the eighteenth-century pattern of employing a taxonomic approach. Diseases have as their proximate causes certain pathological states that are, in general terms, disorders of the bodily solids, of its humors, or of combinations of the two. As further elaborated, "Boerhaave's system incorporated a profusion of pathological states for most of which there was no objective evidence." [93] This gap between clinical description and speculative explanation, as well as the appeal to humors, is also characteristic of Hutton's closing section on diseases of the blood, a subject Boerhaave dealt with at considerable length himself.[94]

Hutton's theory of respiration is equally Boerhaavian. To provide a compelling iatromechanical account of respiration, Boerhaave first denied the truth of several received theories and then claimed that respiration links the mechanical property of elasticity to the physiological functions of heat production and the assimilation of nutrition.[95] Both the ancient physician Galen and the modern philosopher Descartes followed Aristotle in considering the heart the source of bodily heat, which was then distributed by the blood. But, Boerhaave argues, while the blood may be slightly cooled in the lungs through contact with the air, this is an accidental rather than an essential effect, and certainly the "fuliginous" fumes which Galen supposed were given off by the fire in the heart are not released by the blood in the lungs. Equally false is the notion, again traceable back to Galen but most fully elaborated by modern chemists, that in respiration the blood acquires a spirit from the air that nourishes the body's "vital flame." For the iatromechanicians, bodily heat is caused primarily by friction between circulating fluids and the walls of the vessels through which they flow, and since the blood vessels of the lungs are especially small and convoluted, it is only reasonable to assume that during respiration more bodily heat is generated than is lost. The passage of blood through the vessels of the lungs also strains and breaks up partially digested food particles in the blood and thereby completes the process by which nutrients are assimilated by the body: "Hence we discover the Lungs to be the principal elaboratory of Sanguification, and for converting the Chyle, which is all brought hither, into *nutritious Juices*. . . ." Air acts to bring about these effects by virtue of its elasticity, which enables it to inflate the lungs and thus open the passages through which the blood must flow. If the supply of fresh air is cut off, the lungs cease to function when the elasticity of the air available to them has been exhausted: "What then have we in confined Air to account for this, but the Destruction of its Elasticity, whence it will not be able to distend the Lungs, nor maintain Fire or Flame, etc." Thus, Boerhaave concludes, in respiration no air is absorbed by the body or mixed with the blood. Air contains no "aerial ferment" or vital spirit and acts to sustain the vitality of animals solely through its peculiar mechanical property of being elastic.

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[90] See C. J. Lawrence, "Early Edinburgh Medicine: Theory and Practice," in R. G. W. Anderson and A. D. C. Simpson, eds., *The Early Years of the Edinburgh Medical School* (Edinburgh, 1976), p. 81–94.

[91] Ibid., p. 82.

[92] *Cf.* Hermann Boerhaave, *A Method of Studying Physick*, trans. Samber (London, 1719), p. 254: "Now all those who wrote before the Year 1628, whether *Greeks* or *Latins*, are good for nothing; for they were Strangers to the *Harvean* System of the Circulation of the Blood. For this is the only principal Cause on which depends all the rest." On the chemical analysis of blood, urine and other bodily fluids, see pp. 107–111.

[93] Lawrence, n. 90, p. 83.

[94] Boerhaave's account of the chemical disorders of blood is given in Hermann Boerhaave, *Dr. Boerhaave's Academical Lectures on the Theory of Physic, Being a Genuine Translation of his Institutes and Explanatory Comment,* (6 v., London, 1742–46), **5**: p. 341. The explanatory comment consists of the full text of Boerhaave's lectures as recorded by Haller. Prorессor John Rutherford also described the chemical disorders of blood in his Boerhaavian clinical lectures in Edinburgh; see Lawrence, n. 90, p. 87.

[95] See Boerhaave, n. 94, **2**: pp. 92–126.

Stephen Hales was in complete agreement with Boerhaave on the question of respiration. In his *Haemastaticks* he performed an experiment that showed "with how much greater Rapidity the Blood passes thro' the Lungs, than thro' any other capillary Vessels of the Body; whence we may with good reason conclude, that it principally acquires its warmth, by the brisk, agitation it there undergoes."[96] He also describes an experiment performed by Boerhaave in which various small animals were placed in a sugar baker's drying oven so that the effects of the heated air on their respiration could be observed. The cause of death in these cases was, according to both Boerhaave and Hales, the undissipated heat of the blood, "whence he [Boerhaave] justly infers, that as the Blood is most heated in the Lungs, by reason of the great Velocity and Friction it there undergoes, so it is there also most refrigerated."[97] Hutton also refers to these experiments, in one of the rare instances in which he identifies a source, and everything he says about respiration conforms entirely to the iatromechanical doctrines of Boerhaave and Hales (LXXVI).

While the doctrines advanced by the iatromechanicians were largely successful in displacing chemical theories founded upon the belief that the life of the individual is sustained by a vital principle acquired from the atmosphere in respiration, they could not completely avoid appeals to the chemical notions of active matter. As we saw above, Newton and his followers, when addressing the theoretical challenges raised by chemical action, had to employ the conceptual apparatus of that science. When Hales undertook to explain how air loses and then regains its elasticity, he too used the well-worn acid-alkali theory and a chemical theory of fire. Hutton too, while entirely iatromechanical in his theory of respiration, followed Hales in reintroducing the fire and ferments of chemistry to explain the properties of air that were central to his physiological theory (XXXVIII). One way to characterize this recasting of iatrochemistry is to say that with the banishment of the spirit or pneuma from nature and the exclusion of vital principles from the body, activity in nature came to be located in the matter described by chemists. In their zeal to demystify medical theory the iatromechanicians declared, to quote Archibald Pitcairn, that "there are . . . no ferments at all in an animal body,"[98] and in his account of digestion Hutton said nothing to contradict this. But in the larger realm of nature fermentation is an operation of indisputable importance, especially in rendering vegetable substances suitable for animal digestion (LXXIX). Thus by focusing on circulatory systems that link animal existence to the encompassing cycles of the macrocosm, Hutton was able to reintroduce a theory of active chemical principles without directly denying the iatromechanical doctrines that were the orthodoxy of his youth.

The intrusion of a new or at least newly emphasized faith in chemistry can also be detected in Hutton's approach to the analysis of blood. Boerhaave described the products obtained through chemical analysis of blood but then cautioned his students that the substances isolated "are not the natural but factitious Principles of the Blood, produced or made by the Intensity of Fire."[99] His opposition to all chemical explanations of the blood was grounded on the belief that analysis by fire cannot be used to isolate simple substances because the fire transforms them during analysis. He shared this suspicion of analysis by fire with many of the best practitioners in the eighteenth century, men who in turning to analysis in the wet way inaugurated an experimental tradition of great importance to the founding of biochemistry.[100] But his criticism of analysis by fire was also a tactic in the campaign against philosophical chemistry. Nothing could be more revealing of Boerhaave's desire to limit the ambitions of chemists than the following passage:

> Chemistry is the Observation of those changes which arise in different Bodies from the Application of certain degrees of Fire; so far as it exhibits Experiments, it may be certainly relied upon; but our Reasonings in it are often fallacious. . . . If any one remarks the Principles which are obtained from Blood applied to a certain degree of Fire, he will find there first ascends Water, then Salt, and in the Retort remains an Earth. . . . Of these Facts one cannot be deceived; but if you shou'd by hasty Reason conclude from this Experiment, that the Blood therefore contains such Salts and Oils as you thus obtain, it wou'd be an Error with a witness; if a chemist takes upon him to account for the Appearances of Bodies, he forgets his own Character, and acts the Part of a Philosopher, or too often, of a Rhetorician.[101]

Hutton, unlike Boerhaave, refused to accept the critique of analysis by fire as a general argument against the chemical philosophy. He used both fire and solvents in his analyses of blood, and while careful not to claim that the principles he identified were elemental, he insisted that they could be made the basis of an explanatory theory. It is this confidence in the theoretical possibilities of chemistry that distinguishes Hutton's dissertation and sets it apart, if only in conception, from the works of the authors he read and the teachers he studied under in Edinburgh.

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[96] Stephen Hales, *Statical Essays: Containing Haemastaticks,* (2 v., London, 1733), **2**: p. 90.

[97] Ibid., **2**: p. 102.

[98] King, n. 81, p. 115.

[99] Boerhaave, n. 94, **2**: pp. 167–168.

[100] See Frederic L. Holmes, "Analysis by Fire and Solvent Extractions: The Metamorphosis of a Tradition," *Isis* **62** (1971): pp. 129–148.

[101] Boerhaave, n. 94, **1**: p. 46.

There were, of course, other physiological phenomena that defied explanation and could only be approached through cautious speculation. One such topic was muscular action, a subject of special interest to Frederik Winter, the Leiden professor who presided over Hutton's admission into the company of physicians. It seems likely, as Professor Ellenberger has suggested, that the long section on the action of muscles in the dissertation was written under Winter's direction during Hutton's stay in Leiden (XLIII).[102] Hutton's argument is interesting. He begins by clearing the ground, insisting on the inadequacy of "all the mechanical formulas and principles which can be brought to bear upon this issue" and the absurdity of invoking all the "chemical effervescences, rarefactions, explosions, etc. [that] have been postulated here." He then hesitatingly proposes that the muscles may be moved by "some active and potent cause which is, perhaps, entirely different from any chemical, mechanical (etc.) law thus far known to us" (XLIII). If we are to know anything of this cause we must reason by analogy, the analogy Hutton has in mind being electrical phenomena. Of course many natural philosophers before Hutton had analogized to electrical and magnetic phenomena when speculating about physiology. What makes Hutton's thoughts noteworthy is his allusion to recently discovered experimental knowledge on the collection and transmission of static charges. What he says is rather vague and inconclusive, but it does indicate that he remained alert to new developments in natural philosophy and medicine while in Leiden.[103] Indeed, given the way he transformed debates in the theory of medicine into broad discussions of chemistry and natural philosophy, it is hardly surprising that he never became a practicing physician.

PART I—TRANSLATOR'S PREFACE TO TRANSLATION

In making this translation our goal has been to produce as readable an English text as possible without violating the boundaries of interpretation set by the language of the original. Latin documents almost always contain certain ambiguities and we realize that our efforts to unravel those we have encountered may not have been completely successful. In a few places our translation reflects the uncertainties of Latin usage and the limits of our understanding of eighteenth-century natural philosophy and medicine. We hope the availability of the Latin text will enable others to detect and remedy such shortcomings as remain. Certain misprintings and other textual problems have been noted in both the Latin and the English texts. In the translation we have also provided a few annotations identifying chemical and medicinal substances.

Our work on this project has been greatly assisted by the unstinting encouragement of Professor François Ellenberger. Upon learning that we had undertaken a translation of Hutton's dissertation, he generously offered to send us copies of his French translation, made with the assistance of his son Marc, and of the scholarly notes he collected while preparing his pioneering article on the dissertation (see above, Introduction, n. 12). These materials, offered, as Professor Ellenberger wrote, "as a modest French tribute to our great Hutton, who once studied in Paris, and afterwards always took a very great interest in French geological publications," were referred to often and proved to be of inestimable value. We hope that readers of this English translation will not forget that it has benefited greatly from this exemplary act of international scholarly cooperation.

Research on this project was supported in part by a grant from the National Science Foundation, to which we extend our thanks. We also are most grateful to The John Crerar Library for providing an excellent photocopy of the Latin dissertation. The two works consulted most frequently during the preparation of the annotations were Maurice Crosland, *Historical Studies in the Language of Chemistry* (London, 1962) and Jon Eklund, *The Incompleat Chymist* (Washington, D.C., 1975). Thanks are also due to Connie Hinzman for her skillful typing.

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[102] Ellenberger, n. 12, p. 509.

[103] The invention of the Leiden jar was announced in 1746 and the following year Benjamin Franklin wrote the first of a series of letters to his friends in London in which he outlined a theory to explain the striking properties of the new instrument. In 1745 Albrecht von Haller began his research on irritability in muscles, a property he distinguished from sensibility. Irritability he considered a property of animal tissue itself while sensibility involves the action of the nerves. Haller believed the nerves contain a subtile fluid but he rejected the idea that it was the electrical fluid. See Roderick W. Home, "Electricity and the Nervous Fluid," *Journal of the History of Biology* 3 (1970): pp. 235–251.

PART II—THE DISSERTATION—ENGLISH TRANSLATION

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PART III—THE DISSERTATION

INAUGURAL PHYSICO-MEDICAL DISSERTATION ON THE BLOOD AND THE CIRCULATION OF THE MICROCOSM

which – –

With the approval of our triune God, And with the Authority of the Exalted University President, Dr. Joachim Schwartz, Doctor of Both Laws and Professor in the Leyden Academy,

As well as

With the Consent of the Full Academic Senate and by the Decree of the Worthy Faculty of Medicine,

For the Doctoral Degree And for the Special Honors and Privileges in Medicine Which Are appropriately and legitimately connected therewith,

James Hutton, Scotsman,

Submits to the critical examination of the Learned, on the
twelfth of September 1749. H.L.Q.S.

* * * * * * * * * *

At Leyden,

In the establishment of Wilhelm Boot, 1749.

To the excellent, respected, learned, and most experienced Gentlemen,
John Stevenson and George Young, Doctors of Medicine, of the Royal College of Physicians, Edinburgh,
James Hutton presents and dedicates these first fruits of his studies as a memorial of due respect and honor.

INAUGURAL PHYSICO-MEDICAL DISSERTATION ON THE BLOOD AND THE CIRCULATION OF THE MICROCOSM.

I. Nature, everywhere the most amazingly and outstandingly remarkable producer of living bodies, being most carefully arranged according to physical, mechanical, and chemical laws, does not give even the smallest hint of its extraordinary and tireless workings and quite clearly points to its work as being alone worthy of a benign and omnipotent God; and it carries this bright quality in all of its traces, in that, just as all of its general mechanisms rejoice, so also do all of their various smallest component parts rejoice in the depth of wisdom, in the height of perfection, and in the lofty arrangement of forms and qualities, which lie far beyond every investigation of the human mind. From the works of current writers this fact shines forth everywhere and abundantly; I also hope to present some things which should be said by someone who considers her quite beautiful appearance.

I do not know to what extent this theme may exceed my abilities; and, indeed, working with such meager resources of time and personal talent, I would not have dared openly to present these disordered pages; however, necessity and the customary procedure in similar circumstances have driven me to it, although reluctantly: and let no one find fault with me for having made an effort in an important matter; but, rather, let this effort, which is almost extemporaneous and of little significance, be received with a measure of good will.

II. Being about to treat of blood and bodily fluids, I shall, as far as possible, ignore solid materials in order to avoid digressions from the main subject-matter, although there exists so close a connection between those related items which mutually give form to and modify one another that it is not easy to determine which of them has prior existence, both advancing in step, one refashioning the other and one modifying the other; and thus they display the glorious cycle of life and a very beautiful instance of perpetual moving —an instance in which matter moves without a material cause, in which it seeks its own special aims on the fertile earth, and in which it reconstitutes its daily diminutions by means of the very cause of its destruction; and before yielding its life-producing movement to the fatal necessity of material machines, it produces new offshoots, which will complete its role in the microcosmic grove.

III. As the animal economy can be analyzed into these functions, namely, sensation, muscular movement, nutrition, the propagation of the species, the production of blood, and the generation of heat (*caloremque generationem*), then, in considering the fulfillment of them, one can gather from the following consideration of its circulation to what extent the blood and its derivatives affect them. Now these functions take place not at all in isolation but interdependently, in a remarkably complicated manner; sometimes one circulation does not serve merely one purpose, and often a simple effect requires several efficient causes: thus the circulation of blood through a muscle serves for nutrition and, at the same time, for muscular movement, the same thing can also be said about the juice of a nerve, and neither of these effects can be achieved without the concurrence of the arterial together with the nervous cause: saliva also assists the function of taste and at the same time the production of chyle: the same sort of thing occurs with regard to tears,[1] abdominal fluid, the synovia[2] of ligaments, marrow, fat, etc.

We must therefore make a few introductory observations about the nature of the blood, which is, as it were, the source as well as the termination of all bodily fluids.

IV. The blood appears to be a highly compounded liquid containing many different homogeneous parts, of which one species is quite distinct from another with regard to form and quality, and some of which produce their effects on the body by reason of their mechanical form, others instead by reason of chemical action.

V. When the contents of a vessel of a living animal are examined with a microscope, one observes many little red spheres floating in it, as well as smaller ones which are nearly transparent.

Each red sphere appears to be formed by the union of six smaller spheres and sometimes they break up into these smaller spheres again.

VI. When blood spurts out of the body, it appears at first to the naked eye to be homogeneous but afterwards it seems to be separated into two substances, the minor part of which takes on a thick, fibrous consistency, which is sometimes almost fleshy, while in its inner part it has a nearly black color, but whenever it is exposed to the air, its color changes to a ruddy red. The other part, the serum, retains its fluidity, although it becomes yellowish and slightly viscous.

VII. Clotted blood coagulates through the union of the red spheres: the fluid part contains only rather thin, watery, and transparent spheres and other parts in a liquid or dissolved state, and weighs less than clotted blood.

VIII. This serum, when exposed at its base to the degree of heat at which water boils, changes into a white coagulum, which, when dried in the air, produces a horny or amber substance: it coagulates with alcohol as well as with mineral acids.

IX. When oil of vitriol[3] is added drop by drop, the serum first coagulates, but when the oil of vitriol is poured on, the serum is clearly dissolved; if one dilutes this solution with water, a white coagulum is precipitated, which, after it is separated from the water, is again dissolved by oil of vitriol as before, and when water is poured on, it separates again by precipitation, and so forth; the precipitate, after being freed from this encompassing liquid and dried by the air, becomes a transparent, hard body: but when the serum is diluted by water, it suffers no coagulation from this acid.

X. When clotted blood is dissolved in water, especially if the water is lukewarm, there is left a residue of soft, white, very contractible filaments; and it imparts to it a blood-red color. When this clotted blood has been dissolved by means of the above-mentioned heat and liquids, it condenses into a dark solid substance.

This solution of clotted blood is precipitated, with a resultant color change, by the addition of oil of vitriol. When this precipitate is separated from the acidic liquid, it becomes partially dissolved in lukewarm water and takes on a darkish color; this water thickens when a very sparing amount of oil of tartar[4] is poured on it, but if the oil of tartar is added a little more generously, it becomes clear again. Those dark solutions are always coagulated by vitriolic acid, as before—although more delicately—and they are precipitated.

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[1] *Sachrymis* in original, clearly a misprinting of *lachrymis*.

[2] The viscid fluid in the interior of joints and the sheaths of tendons.

[3] Sulfuric acid.

XI. Blood which is fresh from the vein and has been diluted by a large amount of water and then coagulated by boiling the water, separates into a soft, granulated, dark-colored substance; and when this substance dries out, it becomes a black and very hard but crumbly body; when the coagulum is separated, the filtered water is tinged with a dark-red color and, when it evaporates in the normal manner, it leaves behind a gelatinous, blackish substance, the amount of which, however, is small: apparently no essential salt was crystallizing here.

XII. Blood, when subjected to distillation, divides up into: a great amount of water, up to 0.73 of its weight; oil of various consistency, 0.053; volatile alkaline salt,[5] 0.035; fixed earth, 0.035; and what is lost in the form of air, 0.147.

XIII. With respect to the subject-matter of the animal kingdom; it contains salt, water, sulfur, earth, and air.

We are not entirely sure that these principles are basic, original and immutable elements; being merely specific differentiations of the animal or the vegetable kingdom, they should not be taken any further by means of human skill.

XIV. Although every pure principle enjoys its own particular powers, still, when it is united with other things in a compound of blood, it cannot act independently upon external bodies applied to it but only through the combined capacity of their mutual union.

For example, let us suppose that A, B, C, and D are different chemical principles which, when combined, produce a small part or part of a small part of blood; and that X is a body or menstruum[6] which has a certain action upon B: the potential either to dissolve it (but only when it is separated from the other constituents) or to combine with it; but when B is joined to the other principles, inasmuch as there are mutual differences, there can be no reaction, however slight; or if the potential for forming a union among them were to remain, it is evident that this compound would be quite different from the combination of mere B with X and that the manner and degree of interaction would be changed so that another body, Y, which could not effect their simple union, would, nevertheless, be more than able to break up this union, compounded from one side; and thereby it would either produce a greater action than X upon the other principles, A, C, and D (as silver precipitates from spirit of niter through the interposition of marine acid),[7] or produce upon X the same effect which the weak salt of distilled vinegar demonstrates upon alkaline salt in the precipitation of milk of sulfur,[8] exerting upon the alkaline salt a stronger action than the vitriolic acid there combined with the sulfurous principle. Furthermore, let us suppose that X exerts a strong action upon B, less upon C, scarcely any upon A, and none at all upon D; then X can be joined to particle A, B, C, D and adhere firmly; if, however, in place of the simple A, B, C, D combination B, C and C, D and A, D were —together or separately—combined all together, then X could exert less action—or maybe even none—upon this more complex particle; but the fact is that if the particle was combined in such a manner that D were hidden, X could have a very much greater action; it could even be so constructed that the action of D, being masked by the union of the other principles, would almost disappear. Thus in crude tartar,[9] although the saline parts openly react against the aggregate in such a way as to give it an acidic character, nevertheless, they are so much blocked and hindered by oily parts that the tartar is hardly soluble with it in water: moreover, when the oil has been separated by fire and again combined with alkaline salt of tartar into a saponaceous saline alkaline substance,[10] this oily-saline aggregate easily enters into an association with water; and although in each particle of tartar and soap the same principles are found, and in nearly the same proportion, still, those particles, on account of the different combinations of those principles, exhibit entirely different actions and characteristics with the other bodies.

XV. When, however, in the composition of the blood, principles have not been merely blended together, united, and combined but these greater and lesser combinations are also joined, thoroughly blended, and remarkably well combined, it is then not possible to make a completely sure *a priori* judgment concerning the nature and the quality of the blood, even though the principles of the blood be known, as well as their actions and appearances.

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[4] Potassium carbonate.

[5] Ammonium carbonate.

[6] Solvent.

[7] When hydrochloric acid is added to a solution of silver and nitric acid, silver chloride is precipitated.

[8] Finely divided sulfur in solution.

[9] Potassium hydrogen tartrate.

[10] The combination of salt of tartar (potassium carbonate) and oil yields soluble soap.

XVI. The water of the blood not only enters into the composition as the menstruum and the vehicle for the other elements, and thus constitutes the medium in which they can act and the basis of its fluidity, but it even enters into their minute solid combinations and into their blendings which are almost primary.

XVII. This is not the place to discuss the nature of the water and its particular properties for here, as everywhere, it is the same simple element, and although it undergoes in combinations various modifications, it does not receive a variety of names and almost always, by its very distinct nature, again separates.

XVIII. Earth provides so difficult an occasion for speculation and one which is cloaked in so much obscurity that it certainly should not be undertaken without seriousness. How much less should this area be considered suited to my intellectual capacity, which is weak and bolstered with a few experiments in this regard! At any rate, we should hope that some light has been shed on this topic. However, thus far the sterile and obscure nature of the subject-matter has either scared off the chemists or induced them to neglect it in favor of some topic with more attractive characteristics; and this neglect perpetuates great ignorance of chemical mixture of bodies, and a great obstacle to our understanding of this earth is posed by the uncertain notion we have of it, the definition consisting, as it were, of two merely negative and passive items.

XIX. As it is characteristic of this principle to be resistant to fire and water, so the earth obtained from the calcination and edulcoration [11] of the caput mortuum [12] left over from the distillation of the blood and the rectification of its oils is commonly presented as being this principle. But I feel that this notion is fraught with a good deal of uncertainty, and perhaps instead one should postulate a certain very firm combination between the earth and the saline principle, wherein their prior actions are, as it were, destroyed or impeded.

Perhaps we see a congealing occurring, after the calcination has been repeated, in the solution and the evaporation of the fixed alkaline salt,[13] where some of it is destroyed and some of it is converted into fixed, inert earth similar to this. I admit that here it appears to be probable that the saline principle is freed from its bond and flies away while pure earth remains. But why is it that its combinatory action is so very much weakened, something that we never see occurring except by blending?

But if we were to characterize the principle by its properties and immutable nature, then there would be found many bodies which differ greatly but which claim this dignity with an equal right; and, indeed, in this respect English chalk would in no way yield to this earth in the quality of the principle.

There are many experiments which illustrate this weakening of the power of the saline principle in combination, such as a saturation with oil of vitriole and alkali salt; indeed, hardly a body can be found which cannot be dissolved by one sort of thing or another; but when joined, they produce a body which at the time of its acting with water, which both of them had in a very firm state before, is now not quite so easily separated from it—at least it has a reaction with it which is quite restricted; and it does not act upon any other body, except by reason of the aqueous and inflammable principle which it contains. The making of glass supplies another example which is quite relevant to our viewpoint, wherein one should take note that an active, fixed alkaline salt, in union with our animal earth (much less active, but soluble in acids), achieves a state than which, perhaps, no body is considered to be more passive.

But what should be concluded regarding the large amount of earth produced by a combination of pure vitriolic acid with alcohol,[14] where definitely no earth exists? Does this not demonstrate that the earth is compounded of salt rather than vice versa? Unless the earth be thought of as being salty, which manner of speaking effects the greatest harm to science by confusing notions, can this earthy principle then develop from a saline principle? Will this not shed some light upon their many abstruse phenomena?

The following experiment demonstrates emphatically this earthy combination of the saline principle: Saturate fresh lime with vitriolic acid, with very little being dissolved;[15] when they come together they do so with effervescence and a lot of heat; when this mass has been well calcined in an open fire, it weighs almost twice the weight of the lime; yet, although there is such a great portion of saline matter in it (let us pass over, in silence, the saline nature of the lime itself), still, it appears under the form of inert earth and does not show even the slightest trace of the saline characteristic; in water, in vitriolic acid, and in acid of vinegar[16] it remains almost intact; it dissolves somewhat in spirit of niter[17] but with great difficulty. But let me get back to the main issue.

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[11] Washing of a solid with water to remove soluble impurities.

[12] Solid residue remaining after dry distillation.

[13] Potassium carbonate; probably containing some sodium carbonate as well.

[14] Alcohol and vitriolic acid yield diethyl ether and a nonvolatile residue.

[15] $CaCO_3 + H_2SO_4 \rightarrow CO_2 \uparrow + H_2O + CaSO_4 \downarrow$. Since Hutton states that this reaction effervesces, his "fresh lime" must have contained a considerable residue of uncalcined limestone.

[16] Acetic acid.

XX. By earth, a principle of the blood, we understand a body fixed in itself and insoluble in water, having a great affinity and reaction with the saline principle, through whose aid it is rendered soluble in water and blends with other bodies; in alkaline salt it is found closely combined with a saline principle and perhaps with water; this combination, when further united with sulfurous or oily matter, produces volatile alkali:[18] it is not contained in ardent spirit[19] and it enters into composition with any vegetable or animal oil, but always when united with a saline principle; in the same way it is thoroughly blended in a fairly large amount in their more compounded salts and juices and in combinations and, even more so, in compositions which are very complex.

XXI. But to get a suitable idea of these compounded earthy combinations, we would have to make a detailed investigation, including careful study in the vegetable kingdom, where [earth] is always found firmly and closely joined to however many other principles; yet by carefully weighing and comparing its [earth's] different appearances in their various vegetable juices and salts, which are sometimes in a simple and other times in a more compounded state, we might be better able to form an opinion about its [earth's] properties and the phenomena which, under these various conditions, it manifests in relations with other principles; we would also observe those changes in them [the vegetable juices and salts] produced by animal circulation; not insofar as it is concerned with its elementary, so to speak, or simply blended state, but only with its complex combinations; for although in all vegetables its [earth's] ultimate nature is the same, by means of its own different combinations and combinations with other principles it produces various specific earths and, thereby, earths which are very much compounded and which are peculiar to various vegetable items, or to the various juices of the same plant, or, finally, to the various component parts of the same juice; they provide much opportunity for modifying their tastes, astringencies and other properties.

XXII. But with respect to animal nutrition and the various actions of vegetable juices upon the animal body, we will find most of these specific compounded vegetable earths to be entirely unsuited for entering into a blood compound; we shall be concerned only with their earths which are general, rather mild and united with bland oils, which are conducive to blood production; for example, astringent earth of gall nuts, cleansing aloe and emetic ipecac are blended with blood with some motion and resultant changes; when, on the other hand, sweet earth of saccharin (as I might call it) is gently introduced, together with other nutrients, it is able to sustain the blood nicely.

XXIII. These nourishing earths undergo rather great changes in the blood, after, perhaps, the thicker textures have broken down and new, very subtile blendings have formed, wherein it [the earth] is united to other principles and other parts with so tight and close a bond that, once distillation of the blood has been started, it ascends to a great extent into a compound of volatile oil and salt; then a small quantity remains which, having been freed by due calcination from the sulfurous niter[20] (? *nitudine*), appears as a pure, homogeneous earth and forms a white, earthy powder, which is very fixed, tasteless, and difficult to dissolve in vegetable acids, unless it is rendered more subtile by means of mineral acid.

We must accept this earth as basic in consistency and form and the earthy principle of the blood, inasmuch as we do not know how to break it down any further.

XXIV. Blood has a saline principle in common not only with vegetable matter but also with the mineral kingdom and anything of an earthen nature that is found in a dissolved or liquid form, that alone is caused through the aid of this one principle; and this is the true primary acid salt from which all other salts, being derivatives of it and compounded to a greater or lesser extent, originate.

XXV. Certainly, and not without cause, it is not considered possible to exhibit a pure chemical principle; but this acid salt is to be found, if not with water, then perhaps well blended in oil of vitriole or sulfur which has been well rectified in a bell jar (*per campanam*).

In vegetable and animal items it is always detected combined with a certain sulfurous or oily substance by which it is rendered so volatile that, rising up together with phlegm, it cannot be concentrated after the manner of mineral acids.

XXVI. This acid enters into mixture or composition with all the vegetable and animal oils; when, in addition, it is joined to their particular earths and oils, it forms their various compounded salts, which are essential or natural.

In many of these vegetable salts the oil has not been so firmly joined to the saline and earthy parts that it does not separate from them by means of distillation, while some black, oily matter which is left over adheres lightly to the saline mass, after the manner of charcoal; then, after this salt has been volatilized by means of an open fire, a fixed alkali salt [21] remains, compounded as we observed above (XX); and in the blending of the animal salts this earthy-saline substance holds the oil so closely incorporated to itself that in distillation it is entirely carried into the air in the form of alkali salt but differing greatly from a fixed alkaline salt [22] on account of its oily combination.

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[17] Nitric acid.

[18] Ammonium hydroxide.

[19] Ethyl alcohol.

[20] Perhaps potassium nitrate (common niter) containing some potassium sulfate.

XXVII. It is, indeed, not very difficult to conceive of the quality and the phenomena of an acid and an alkali as being opposed.

The alkali salt is compounded, as we observed above, through the combination of the saline and the earthy principles; this combination causes very little hindrance to the activity of the earth or to a further development toward union with the acid salt; but because of the solubility of this earth and its readiness to form saline-earthy mixtures—in which this particular alkaline blend, being very slightly saturated, resembles the acid salt—a very strong and vivid interaction occurs between them, so that, when blended in a dissolved state, they rush together with vehemence and boiling and become saturated, that is, they effect a compounding that produces no further combining activity with acid or alkali.

This saturated, or so-called "neutral" combination, although it is fairly strong, still does not enjoy the same degree of pure-salt and earth strength that it had before; for it is always the case that the simpler the combining parts, so much stronger will be the combination, other things being equal; and this can be taken as a general rule in chemistry: thus, when the acid salts of niter, sea salt, and vegetable items are compounded, they combine with alkali salt more or less firmly in accordance with the strength of each one; but they all yield to vitriolic acid, because being simpler, it therefore produces a stronger reaction upon an alkaline body; even a rather well-compounded body, such as copper which has been dissolved in acid spirits, is precipitated by alkali salt or rather simple cretaceous earth; [23] but we should note here that this rule takes place and is to be applied only when different bodies act upon a common body with one and the same principle, as we saw (given above) in the instance of the acid and the alkali, in connection with the oil of vitriol, the spirit of niter, the sea salt, etc.; they react upon an alkaline body only on the saline side, that is, with their same pure acid; but the situation is otherwise when a simpler body, such as silver dissolved in spirit of niter, is precipitated in a more compounded body, such as copper; in this case one must take many other factors into account, for spirit of niter reacts upon the none-too-simple sulfuro-earthy principle of metals; but the metallic principle being quite complex, copper, for instance, can differ a great deal from silver, also the menstruum can react upon its other parts, such as the mercuric-earthy parts, etc.

At this point I am apologetic for merely making mention of spiculae and pores, of sword and sheath: from this source too, one notices how the old struggles and suppressions of acid and alkali rise up anew, etc.

Let me add that fixed alkali salt reacts only upon the saline and watery side of bodies, except with respect to a vitrifying flux; but our volatile blood-salt, because of its oily or sulfurous blending, does not react so strongly upon the saline principles of bodies as does fixed alkali, but it penetrates their fixed saline-sulfurous parts more completely, it even unites with some bodies which repel it, such as Helmont's pellet (*offoe Helmontianae*).[24]

XXVIII. This alkaline combination in the blood is effected by another natural operation, namely a putrefying fermentation, to which the blood submits completely: regarding this operation let us merely observe that in this respect it provides the same resultant reaction as does fire; and in this phenomenon as well as in many other it seems to operate like fire or a secret combustion in the subject's entrails.

XXIX. From what has been stated it is clear why no fixed alkali is given off from whole blood; why, although no volatile salt in a natural state is found in the blood, nevertheless, by a chemical operation it is so readily supplied from it:

Why at times an acid salt can be derived from the blood (in a small amount, of course), which salt, because of the incorporation of oil, is restricted from uniting with volatile alkaline salt, which is contained, like it, in solution in the same liquid and which is even coated by a good deal of superfluous oil.

Why thick animal oil produces a volatile salt; why a thin oil, digested with animal earth or a saline-earthy body yields the same salt.

XXX. As blood has a saline principle, so it has a sulfurous principle in common with the three kingdoms of bodies.

This principle enjoys a nature and properties which are more distinctive than the others, and it does not have the similarity with them that we saw exists between the salt and earth.

XXXI. It is, to a large extent, easily separated from the compound of the blood by the application of fire and free communication with the air, but then it cannot be contained in the pure state but, as it presents us with a sensation of light and heat, it disappears; it is, then, the matter of fire and light which pervades everything, but combined with and, as it were, embodied within principles, it loses its own igneo-luminous qualities until it again be freed from them by an application of fire; it then produces its own effects, as stated above.

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[21] Potassium carbonate.

[22] I.e., volatile alkali (ammonia).

[23] When calcium carbonate is added to an acid in which copper has been dissolved, a precipitate of carbonate of copper is formed.

[24] Potassium carbonate.

XXXII. Does this principle join with all others indifferently, or just with one principle and which one?—this cannot be easily determined; in alcohol it appears to be blended with water; in spirit of niter, with an aqueous-saline substance; in sulfur, with a saline substance perhaps, and with a small amount of a certain peculiar watery combination; in volatile alkali, with an earthy-saline substance; and in various colored bodies with vitrescent earth, through the agency of which it appears to be very much incorporated in minerals—and as it can, indeed, be collected from the sun, so too can it be collected in this earth, even in a large amount, as in the examples of calx of saturn [25] and Regulus antimony.[26]

XXXIII. In our present subject it exhibits the phenomenon of flame (by reason of its aqueous blending) and, when it is combined with much earth and very little water, it is released by the operation of the fire, only in the form of warmth and it is, indeed, probable that if it had been combined with earth without an admixture of water, then it would even resist this warming operation, as we have seen happen in the mineral kingdom; or could anything of this kind occur in fixed black resin (*terebinth*) of sulfurous balsam, or in the caput mortuum of sweet spirit of vitriole? [27]

XXXIV. Now, let us see how it constitutes a flammable matter which serves the blood to advantage. This principle, combined with much water and also the earthy and the saline principles, compounds into an oily substance or what is called "oil," which varies especially in accordance with the quantity or the varying specific quality of the earthy combination, at one time moist and rather watery, at another time thicker and developing almost a solid form.

This oil undergoes changes with respect to its consistency and its many qualities that are very positively promoted by the heat produced through the working of digestion, whereby peculiar new combinations take place among its principles so that, although they do not alter the oil's crasis,[28] they do influence its nature to a great extent; as a result the oil changes from tasteless to pugently foul-smelling and emphyrematic,[29] from clear or whitish to red, and ultimately, it usually becomes quite black and thick; by distillation and cohobation [30] it becomes more and more thin, clear and penetrating, while there always remains a separation produced by a certain small amount of saline phlegm and there remains earth, combined with the sulfurous principle and, very sparingly, with water, resulting in a kind of charcoal.

It is well known how much this oily matter resists union with water and yet, how easily it is made to mix with it under the influence of a saline substance; but it is not generally as well remarked how the oiliness or flammability of this matter is concealed when it is in a compound with bodies which provide scarcely any clues of this; an example of this is furnished by the production of our subject, volatile alkali salt [31]—who, after examining it in many ways, would suspect the existence of flammable matter in it? Yet who, after thoroughly and properly considering the phenomena of its formation and observing its being consumed by fire when not just sal armoniac but even separated sal armoniac is thrown into niter [32]—who can deny it?

XXXV. Thus this flammable matter, and the oils produced therefrom, enters into various compounded mixtures and submixtures with the other constituent parts of blood, as we also observed above: but apart from these rather close combinations, a portion of the bland oil also enters into the composition of the blood, almost, in some respect, like oil in a fine emulsion, and so it separates readily and is again absorbed in the functioning of the blood; this, however, may not hold for blood itself, but only to the extent that it contains chylous matter.

XXXVI. Now only the principle air remains to be considered. As the notion or definition of air is quite obvious and the name of element is universally accepted, it will then be foreign to the main theme to attempt to question its elemental right here, whether the same item which entered into a compound with the bodies be separated from them or whether it be generated anew: one who prefers this latter hypothesis can readily point out the possibility of such a generation from the phenomenon of the expandable vapors of boiling water, which produce, temporarily, an appearance but then the true character of the air, only they do not endure; and what if one were, furthermore, permitted to give an opinion regarding its composition, to judge it, as is probable from its name, to be a peculiar combination of a sulfurous principle and water—wouldn't this shed some light on the nutrition of vegetables through inspiration?

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[25] Lead oxide.

[26] Metallic antimony.

[27] The non-volatile residue that remains when diethyl ether (sweet spirit of vitriol) has evaporated after the combination of alcohol and vitriolic acid.

[28] I.e., its distinctive constitution.

[29] Tasting or smelling of burnt organic matter.

[30] Repeated distillation.

[31] Ammonium carbonate.

[32] Sal ammoniac (NH_4Cl) + niter (KNO_3) $\rightarrow$ nitrum flammans (NH_4NO_3) + salt of Sylvius (KCl). Ammonium nitrate is a well-known explosive.

But back to what concerns our subject.

XXXVII. By distillation and putrefaction air is obtained from blood in a fairly large amount.

From an analysis of vegetable substances it will be known that almost all of this air enters the blood condensed with other principles in foods, also the expandable air goes into the stomach together with the foods and in the stomach and in the bowels, often at the time of digestion, separates from them; often its elasticity can be destroyed to a great extent and condensed by the animal vapors and thus carried into the blood together with chyle; this can also take place, in some way, in the lungs, after some portion of the condensed air has been absorbed in the veins; but by no means is air found through this reasoning to be so very necessary to animal life, nor should we conclude that a great amount of air enters the chambers of the lungs after being condensed by respiration.

XXXVIII. How so great an abundance of air can be condensed and stay in the blood in so inert a state may be readily conceived:

In that we have considered the air to be a mass of particles endowed with a certain repellant force, etc., and that this repellant force depends upon a definite disposition of the air particles, once this disposition is altered, the repellant or expandable force is completely lost, or perhaps just partially lost, in accordance with the degree of the alteration; for example, two electrified bodies repel one another but, if the electricity is removed from one of them, they are attracted to one another, if it is removed from both of them, they are neither attracted nor repelled.

Or, as another example, a lead sphere is suspended and electrified and another sphere of saturn glass is brought towards it: they will repel each other; but when you bring the latter glass back to the lead, after adding just a very small amount of lead, then they will by no means repel but will, instead, attract each other.

In the same way elastic particles of air which are repellant can, when combined with other heterogeneous particles, lose their elastic or repellant quality and result in blendings as solid inelastic compounds and yet later on, after being disentangled by the activity of fire or fermentations, they can once again recover their former elastic quality: it is probable that in this fashion a very large amount of the air's elasticity is destroyed in the lungs, etc. by animal vapors, or by other sulfurous vapors which, when thoroughly blended with the air, can combine with its particles and adhere to them, destroying or at least substantially reducing their elasticity in the manner already stated.

XXXIX. So too the effect which air, when it is broken up by combustion or sulfurous vapors, produces upon the respiration of animals has as its cause not the absence of vivifying breath but this air's very great unsuitability for distending the vesicles of the lungs. Air of this sort affects the lungs (first) by its polluted nature, being weighed down with vapors which weaken its elastic force, whereby (second) it brings partial spasms (third) upon the vesicles, as the pure air does not forcefully extend the vesicles but to a large extent destroys the elasticity of the air already contained in them, as can be seen through the mixing of clean air with polluted air in which much of the clean air is absorbed; (fourth) by mixing this impregnated air with the absorbent animal vapor exhaled from the lungs, not only can its elasticity be much further reduced (as is made apparent by placing a candle or an animal in the air containing these vapors where, although they may not stay alive for half as much time as they might if they were in the same amount of pure air, even so they destroy twice as much elasticity) but also by these combinations there can be formed thick particles, which by adhering and, perhaps, by obstructing the very small orifices and very narrow communication ducts of the vesicles definitely hinder the movement of the lungs as well as the circulation of the blood.

That the vivifying virtue of air depends solely upon an alternating distension of the lung is apparent from the very clear demonstration of the very learned Hales,[33] who kept a dog alive for a long time by, with the force of a bellows, distending its lungs with air which was impregnated with the vapor of burning sulfur, etc.

Hence, when the animal collapsed with heart failure caused by stagnation of the blood, having been left to itself and lacking the strength to dilate its thorax, it died; if, however, with some stimulus or blowing, pure air were again admitted into the vesicles, the animal would be revived with no resultant harm, as is seen in the experiments conducted at Grotto del Cani, when people were nearly suffocated by the vapor of coals.

XL. Having already presented some phenomena of the blood outside the body, we should now hurry on to its vital flow and the functions that depend on it.

XLI. The blood held in the heart's left ventricle is forced out in systole, to the amount of maybe roughly one ounce, into the aorta, which yields to its increased diameter; when squeezed out from here by its elastic contraction, it rushes where an opening presents itself; at first it finds one in the two coronary arteries, where, at the time of systole, because of the application of the valvules to their orifices, it would not have been able to flow; it is pushed forward through all the tiny ramifications of the vascular system, where it applies itself to the employment of nutrition and muscular movement.

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[33] See Stephen Hales, *Vegetable Staticks: Or, An Account of Some Statical Experiments On the Sap in Vegetables. . . .* (London, 1727), Experiment CXIV, pp. 252–260.

XLII. The proper matter of nutrition is not to be determined easily. The transparent, thin, serous lymph which flows through all the points of the body, even the very smallest, is the most likely candidate for this role of nutrition-restoration. Can it be that the nerve juice forms truly solid parts? The blood is found to be entirely unsuited for performing this task in the narrowest vessels. Now it is possible that they all serve toward this purpose, at least instrumentally; and it is possible that nature makes use of not one particular part of the animal fluids but two or more, according to its essential needs, either to make up for its deficiencies from attrition, etc., or to extend, to prolong, or to make new accretions.

XLIII. But in what manner this arterial fluid leads to muscular movement is a much more difficult subject to investigate. Many, indeed, are the conjectures of learned men in this field; in almost all of these conjectures there is posited a flowing together of arterial and nerve fluid, by some, perhaps, there is posited a need merely for the nerve fluid.

But it is not clear enough how these appropriate rarefactions, inflations, infarctions, and distensions, which are supposed to shorten the muscles to such an extent, occur.

And, indeed, all the mechanical formulas and principles which can be brought to bear upon this issue are by no means able to [explain how] muscles achieve as much force in their operation as is observed to be the case.

It is known that in the application of mechanical formulas velocity changes into momentum and vice versa; however (with consideration, of course, being given to the friction of the instruments), an equivalent always emerges, nor is any new force generated therein.

Where then should one look for the velocity of, or where find the momentum of, this muscle-moving cause?

And what about the heart beat: when, indeed, it is measured by a most careful calculation, can an equivalent be found? And if such is the case, what moves it?

Or is the simple influx of nerve fluid sufficient?

Well then, it is with some appearance of probability that chemical effervescences, rarefactions, explosions, etc. have been postulated here; they do, of course, allow for great force; but it would be absurd to suppose their occurrence, when all observation is opposed to this.

We also see great force produced by the dampening of ropes, but there is a big difference between this phenomenon and those of a contracting muscle:

Can it be for this purpose that a thin liquid is infused from the nerves into the fibrous texture of the muscles? This liquid could, in accordance with the judgment of one's mind, remain in it or be suddenly removed by a certain vascular artifice; this is, of course, difficult to conceive and should not be considered sufficient. This is clear: that fibers which are not twisted, such as hair, are not at all contracted by humidity but are protracted by it.

If it were permissible for me to present my own unimportant opinion after so many attempts on the part of such wise men, I would think that here it is absolutely necessary to call on the aid of some active and potent cause which is, perhaps, entirely different from any chemical, mechanical (etc.) law thus far known to us.

But what decision should we make about a cause which is entirely unknown?

We should decide to aim at this cause alone as our guiding beacon and try to demonstrate by analogy, by comparing it with other phenomena of nature, the possibility of such a thing and suggest some observations:

Are we, then, not able to believe, first, that muscular movement is achieved by a simple contraction of the component elastic fibers against themselves, without, indeed, the supposition of a cavity, much less an inflation, of fibers.

Second, that this is accomplished by a fairly great increase in their contracting, elastic power whereby they naturally contract when they have been dissected, etc.

Third, that this elastic or contracting cause is activated by the influx of the fluid of the nerves together with the collaboration of arterial circulation.

Certainly this power of contraction depends upon some hidden material law which has not yet been clearly enough observed by us or it is effected by virtue of some subtile active medium which very readily penetrates all bodies but acts upon them under certain conditions of theirs.

Nature provides many instances thereof, as will be seen in what was mentioned above (XXXVIII); furthermore, it will be seen in the phenomena of a magnet and iron where, among other things, there is an attraction different from that of gravity in that magnetic attraction is severely limited by certain conditions, whereas gravity, by contrast, always works with equal effect in every condition of matter; yet gravity either operates by means of a material law, that is, under the auspices of a subtile medium, or it depends immaterially and immediately upon the will of the almighty Godhead.

Can this be applied to muscular movement? Well, it is not at all proper to go too far with the imagination wherever nature's plan exceeds our talent.

The phenomenon of thunder teaches the amazing effect of subtile media upon bodies that are endowed with a peculiar modification: it hurls a sword through an intact scabbard, and it bruises bones without damaging skin, etc.

Rays of light or a luminous medium are reflected from a white object, but when the color is simply changed to black, they are, for the most part, absorbed and produce a different effect insofar as its production of heat is concerned.

We know that bodies expand and contract because of heat and cold and that this is in proportion to their specific levity; also, a greater degree of cold can be produced from a blending of two bodies and, hence, a greater contraction.

And the phenomena of electricity nicely illustrate how much two bodies in a mutual application can modify so potent a medium.

Indeed, by a little friction of an electric body [34] upon another, non-electric body, an attractive (etc.) force is stirred up and communicated at any distance through the non-electric body without any sensible interval of time; and this transmission takes place not along the body's surface, but, as confirmed by experiment, only through the inner substance; and, for example, it is transmitted through the substance of a very thin golden wire with the same abundance as through a large body endowed with a free surface; and these forces can be so modified and, as it were, increased by the particular application of electric and non-electric bodies that with the addition of just a tiny filament the wire can produce a shock which, while barely perceptible in animal bodies, is powerful enough for one to notice the results of its application.

Can an animal be considered to be a kind of electrifying machine? insofar as it will be constituted of non-electric and electric parts successively applied against and interacting upon one another.

Can the friction of the blood's globules against the walls of the capillaries excite a force analogous to electricity, which also, like electricity, would not manifest itself except by a certain special application of matter?

Can this force be so modified by a special application of electric solids and non-electric fluids that it can produce an effect which is occasionally strong, analogous to an electric shock, and can this be a force which is directed by a decision of the mind, with an application, to be sure, of nerve fluid?

Finally, can the nature of this force be such that it causes the muscular fibers to contract powerfully, as though their elasticity were increased? But let us get back to circulation.

XLIV.The blood which passes through the smaller arteries, which become constantly smaller in their subdivisions, is separated into its various constituent parts on the basis of their size.

XLV. Thus by means of the tiny lateral ducts there is carried off a part of the serum and the thin lymph, which moves around very slender vessels and will perform the function of nutrition there; and part of this lymph, when, perhaps, its function has been carried out, is exuded in the form of sweat or vapor from the entire external surface of the heart for the purpose of moistening or lubricating the whole cavity of the pericardium; then it is to be taken back into the absorbent vein orifices.

XLVI. Not all of this nutritious lymph returns to the blood, which goes back by means of the venous extensions of the arterial capillaries, but it is carried in its very own vessels when it crosses through the various lymphatic glands, and finally flows into the thoracic duct.

XLVII. Thus the blood has been deprived of part of its lymph and an oily material is separated from it and, in turn, reabsorbed everywhere in a cellular substance; and the blood, carrying off particles which have become useless to the body, is pushed into the vena cava by means of the veins which join into major trunks.

XLVIII. Thus is completed one circulatory subsystem of the arterial blood, which can be called the nutritional circulation, and it is found to be the same almost throughout the whole body, whether it flow in muscles, in membranes, or in bones.

XLIX. Now another circulatory subsystem of the arterial blood remains to be considered, namely secretion.

The blood, after being carried from the aorta, through the various arterial developments of the aorta, into the whole body, is carried into the glands, organs of secretion, by means of their own arteries.

L. How the various secretions take place has no relevance to this brief dissertation; it depends particularly upon the special mechanism of separating and absorbing cavities and vessels; although the effect obtained by an infusion of various liquids may be successful in a mixture of water and oil, it can nevertheless scarcely be applied to liquids which quite easily blend with one another.

LI. The secretion which is the most important and of the greatest necessity but at the same time extremely obscure, controversial and, indeed, not the least bit demonstrable, is performed in the brain and is confirmed only by reason and analogy.

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[34] A body that can be given a static charge by friction, i.e., a non-conductor.

LII. The blood, after going straight through the carotids, has its force much restricted in the angular turns at the base of the cranium; having been distributed, thereafter, through the cortical substance of the brain and the cerebellum, which substance appeared as a mass of very tiny vessels—there it does not appear to be red but because of the very thin division it has an ashen color, and here it seems to separate—this vital fluid, which is so necessary for every function, action, and sensation of the body and about whose nature we know so little, and, apart from its being fluid and thin we cannot, perhaps, form any other correct notion in our mind, we imagine that it is carried through the whitish fistulous substance of the medulla and there, perhaps, it is made more complete; then it will circulate in and be distributed through those rounded, tubular fibers, which are in various ways united, separated, and alternately blended with one another through their lengthened extensions, into every point of the body for the benefit, perhaps, of sensation, muscular movement, and nutrition.

LIII. When the secretion of this brain fluid has been completed, the blood, just as in the circulation of nutrition, is led back through veins which gradually become larger as they come together and which run in the major trunks along the depressions between the brain's convolutions; then the blood is transferred into the sinuses and from here through the jugular veins into the vena cava.

Now we must pass on to the more obvious secretions.

LIV. In the tear gland there is secreted a transparent, saline-watery fluid, of a cleansing nature, not the least bit acrid, admirably suited for its duty, which is to keep clean the surface of the eye's corneal tunic, as well as to polish it, nourish its transparency, ease the movement of the eyelids and, after being taken through the tear ducts, to go into the nose for the sake of moistening, cleansing, etc. hardened and dried-up mucus.

LV. The parotid, maxillary, sublingual, and pancreas glands secrete a thin, transparent, and almost tasteless liquid, which has no identifiable smell, is saline-aqueous-saponaceous and is somewhat analogous to a saline-saponaceous liquid produced from a saturation of volatile alkali with spirit of vinegar;[35] it is among the principal instruments of chylification.

LVI. This liquid, having gone from the salivary glands into the mouth, renders bodies savory by applying them to the nerve papillae in a dissolved liquid state; at the time of chewing, a large amount of it is mixed with the foods; it dissolves and dilutes them, it thoroughly mixes and unifies their heterogeneous parts and, indeed, it weakens and subdues their virulent and poisonous qualities.

This pulpy matter, after being carried off into the stomach, dissolves and breaks up from the heat and the fomentation of a well-prepared place, with the aid of this salivary juice, and there commences the transformation of its undigested vegetable character or its assimilation into an animal nature.

All of these things are further carried out in the duodenum through a blending of pancreatic and other juices, with which we shall deal later.

LVII. There follows a juice secreted in various areas through the body either by small spherical glands or by rather large conglomerate glands—secreted especially for the benefit of solid parts, to protect them from injury coming from pointed and sharp bodies, to lubricate passageways, to facilitate the movement against one another of solid surfaces, and to hinder their attrition and heat.

This juice is much thicker than the previous one; its natural character is bland, oil-producing, saponaceous, somewhat sticky, and mucilaginous.

It separates from the blood on the inner surface of the nose, the mouth, the throat, the esophagus, the stomach, the entire intestinal canal, the ureter, the urinary bladder, also in the prostate of men and the mucous glands of women, in the urethra and on the inner surface of the genitals of both sexes, and finally in the integuments and the mucilaginous glands of the joints.

LVIII. Some of this mucilaginous juice is eliminated from the body like a kind of excretion and some, such as in the mouth, etc., is blended with additional items; it is weakened in order to make acrid matter sticky and soft, and in order to make the oily parts in a lactescent form miscible with watery parts; this last effect is very well demonstrated in the union of medulla oil with the watery lymph of the joints to produce synovia; this synovia after it is taken back into the blood, produces very beautiful effects, as it softens the acrid matter by means of its balsamy nature.

LIX. In the eyelid glands and throughout the various sebaceous glands, including those of the auditory passageway, there is secreted a thick sebaceous liquid, which provides a salve for the protection of the skin, etc.

LX. As we observed above, a bland oil is restored everywhere throughout the body between the solid parts and into the cavities of the bones, and it is separated in the cells more or less on the basis of location; it is of beneficial service to solids and especially to fluids, as is seen in the cases of fevers and of strenuous exercise; it is so arranged that it is received into the blood in the greatest amount when there is the greatest need for it, namely, at the time when the blood is tending towards an alkaline acrid state; and it is known that this acidity is greatly mitigated by a combination with linseed oil.

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[35] Volatile alkali (NH_4OH) + spirit of vinegar ($HC_2H_3O_2$) → vegetable ammoniacal salt ($NH_4C_2H_3O_2$) + water (H_2O).

LXI. A black pigment, which gives color to the choroid, is secreted there for the benefit of vision.

LXII. We also observed above that the thin lymph fluid is exuded from the surfaces of all of the internal cavities and is received back again into the absorbing veins: in this way, also there is supplied a watery humor which gives support to the form of the eye.

LXIII. Through the entire extension of the skin there is a similar secretion, which provides for sweat and matter which can sweat and it not only keeps the skin moist but is considered to be necessary for eliminating useless and offending matter from the body: therefore, it is held to be excrementitious.

LXIV. A thoroughly excrementitious secretion is performed in the kidneys, and it is extremely necessary for the benefit of the blood.

The blood is carried swiftly and in a large quantity through the glandular substance of the kidneys; there is separated from it the saline-watery lymph-fluid, which drips through the ureters into the pelvis and flows into the bladder; when freshly secreted, it is very clear, mild in taste, and of a great quantity, but in its passage through the pelvis and the ureters, and into the bladder, its mild lymph-liquid portion is carried off in absorbing vessels, and the remainder, which is impregnated with acrid saline particles and other excrementitious items, gets the name of urine.

LXV. As the urine which is to be rejected from the body no longer mixes with the blood, we must, then, abstain from any further consideration of it; but since this secretion is found to be so useful for the good disposition of the blood and absolutely necessary for preserving it, and so that due attention to the phenomena of this secretion and to the basic nature of urine may shed some hardly-to-be-despised light on the healthy as well as the sickly condition of the blood, I trust, then, that my efforts with regard to the following observations will not be foreign to my main theme.

1. From urine, when a large amount of superfluous water has evaporated, there is obtained by chrystallization a salt which is soluble, pungent, saponaceous, and detergent, not manifestly acidic or alkaline; this is the essential salt of urine and it is sufficiently well compounded so that, when the saline principle and the earthy principles have been so closely blended and combined between and among themselves as well as with oily parts, with a slight application of fire it goes up into a combined, volatile alkaline salt for the most part; and it is so amenable to this combination that it is easily obtained in a dissolved form through digestion alone, especially when induced by heat.

2. No such salt is found naturally in foods which are commonly used by us, but it must be considered as a true creation of the blood only and the result of animal fermentation (by which we suppose it to be just a loosening and combining power).

3. But the salt which is found in the blood is not at all to be considered to be endowed with the same basic nature as that which is found in urine; rather, it should be considered to be conflated from saline-earthy and somewhat weakened saponaceous parts through the aid of digestion, warmth, and intestinal movement; in the same way as from a sweet, rather bland, balsamy wine, by the continuation of intestinal movement or fermentation an acidic, sharp, pungent salt of vinegar is produced, completely different in its quality from the wine from which it is formed.

4. Thus by means of the body's vivifying faculty, there is produced in foods, which have been properly blended and combined, not just in accordance with chemical laws but also, at the same time, fashioned into certain mechanical forms, a bland liquid which is homogeneous or, rather, conflated from various homogeneous parts; which liquid does not act upon the solid parts and upon the other animal liquids, as the particular special qualities of its separated saline, earthy, and oleaginous parts are kept distinct; and, indeed, given a mutual combination and a reaction within and upon themselves, in a compound they are almost completely destroyed and in their place a congealed item results from certain limited, weak qualities; thus when the saline portion modifies the oil portions, this item becomes miscible with water; but it reacts with no other saline property; indeed, when the activity of the saline portion upon the earthy and oily portions has been entirely completed, at the same time these earthy, oily portions give it its consistency, its form, and its mild blandness, etc.

5. Since the blood is so constituted and since its homogeneous particles are not the least bit simple but are tightly compounded, therefore, inasmuch as warmth and agitation are so conducive to change, their component parts cannot stay in the state in which they are arranged; but, in accordance with chemical laws, they are forced to react upon and among themselves, as a result of which various changes of texture and conformations are produced.

6. Thus will the earths and the compounded oils be more and more worn down and reduced, not only by

the action of the saline parts which are united to them but also by the action and the freeing of the saline principle contained in them, insofar as they are compounded of oil and earth, and they will become sharp and soluble, and the saline portions will enter into tighter combinations.

7. And as everything is contained within a watery vehicle and necessarily acts therein, the portions, then, which have the greater action with this medium, that is, the saline portions, will move and react with the greatest activity and will achieve, as it were, dominion over the other portions; from this there will be formed soluble concretions, saline-saponaceous, sharp, and, because of the gentle blend of saline, earthy, and oily parts, tending towards an alkaline combination.

8. Just as this breakdown is developing in a particle of the blood, some of it, which is changing and gradually becoming unsuited to the blood's crasis through the action of a watery medium, is loosened and separated from the remaining portion of the particle and it dissolves in the watery medium.

9. Thereupon it becomes more and more acrid and, by irritating solids and acting upon their soft parts and upon the blood, it becomes completely injurious to the animal economy.

10. Once this degenerate matter has been separated from the blood's crasis and has acquired its urinary character, it cannot reacquire its former nature or again enter into a blood compound, just as vinegar never resumes the nature of wine: urine, then, is not very nutritious but just the opposite; and although it can be of some use to someone who is provided with mild solids and with cool, gentle liquids, still, for someone who is fairly healthy, as much good as it brought to the former, so much harm will it bring to the latter.

11. But if, through some causes, a chemical degeneration were to be effected in a certain portion or component part of the particle or globule of blood, it could not be freed and separated from the globule; but if it should happen that excrementitious matter were not only not eliminated from the body but, furthermore, were even to be combined in a blood compound, would there result therefrom an obvious change in the crasis or consistency of the blood?

And would there not necessarily result therefrom a stimulation, a warmth, and a fever, which, as it continually aggravated its cause, would become more and more inflamed, until the offending matter were loosened, dissolved, and separated through an appropriate cleansing.

12. Is this digestion and a critical evacuation?

13. Is it because of this that the empyreumatic oil of stag's horn, for example, which is thick and gluey and which blends with blood by means of sweet fruit juice or similar items, stimulates abundant warmth and a rather long-lasting fever, one caused by the gluey quality of this oil, which makes it hard to break up, dissolve, and separate.

But this oil, when the distillations have been repeated, becomes clear and thin; it stimulates (etc.) only for a short time, for it is quickly broken up and expelled.

LXVI. A final secretion remains to be considered, which, certainly, does not yield to the others in worthiness and nobility of function, in that it is concerned with the propagation of the species.

A very clear fluid is secreted from blood which has been carried through the spermatic arteries into the testicles, into their vascular, wonderfully convoluted substance; this fluid passes through the vasa deferentia and is stored in the cells of the seminal vesicles.

Here it undergoes a change of consistency, if not of quality, after the more watery portions have been absorbed.

When one dilutes this bland, mucilaginous spermatic fluid with lukewarm water, one observes, with the aid of a microscope, many swimming animalcules.

LXVII. In the circulation of the glands it must be noted that, in addition to the blood which is involved in the secretory circulation, another portion, which has been carried into the gland through an artery or a branch that is generally proper to it, is devoted to nutrition and, perhaps, another purpose.

LXVIII. All of the aorta's blood, which is to circulate through the entire body, after having been distributed, as stated above, for the sake of nutrition, muscular movement, and secretion, is brought back to the heart through the veins which come together into one another and thus form larger trunks, which correspond to the arterial trunks. and then flows into the vena cava.

LXIX. And the blood which has been sent out of the descending aorta through the abdomen and the mesenteric arteries, before heading for the vena cava, goes through two subcirculations, such as have already been described, in this manner:

The abdominal and mesenteric arteries being distributed in the stomach, the bowels, the pancreas, the intestines, etc., for the circulation of the juices of nutrition and secretion, the blood is then gathered from them into their own veins, which form from their union the vena porta, from which the liver is supplied with blood, just as the other glands are from their very own arteries.

But some of the blood of the abdomen, having been sent into the spleen, there effects a very distinctive subcirculation, and then from here it is transferred through the vena porta into the liver (this splenetic circulation seems to be entirely destined for the use of the liver and intended to prepare blood—namely, arterial blood, which is perhaps unsuitable in force and quality—for hepatic circulation by slowing it down, spreading it out, and making it more fluid). This blood in the vena porta, replenished by the absorption of oily particles dispersed throughout the abdominal fluid and excited by sulfurous-saponaceous particles, is transported through the slender vessels of the liver and through its glandular substance, after the manner of arterial circulation, but with a gentle movement produced especially by the action of the diaphragm and the abdominal muscles; and it is gathered together again into veins which grow larger, as before, prior to flowing into the vena cava.

The bile, which has been secreted by this blood in tiny capillaries and gathered together into the liver duct, is in part regurgitated into the gall-bladder; but the greater part flows through a common duct into the duodenum.

This somewhat sticky liquid, saturated with saline-oily parts, diluted with pancreatic juice, and very closely blended with foods which have already experienced the digestive process of the stomach, promotes chylification as best it can by means of its extremely saponaceous quality, which breaks down undigested foods and produces a very homogeneous texture or mixture.

All of this is further advanced by cystic bile which, after its more watery parts have been readily absorbed in the gall-bladder, is stimulated by the heat of digestion and becomes more efficacious, bitter and dark in color, and acquires an almost alkaline nature; so wonderfully regulated is this bile that it produces a kind of animal fermentation in undigested foods, as well as very nicely assisting the functions of the intestines with its exceptional stimulation of heat and intestinal motion.

LXX. When the blood from the liver has arrived at the vena cava, after this subcirculation has been carried out, it completes the return of all the arterial blood which is about to rush into the heart's right auricle.

But it is deprived of many of its parts, which are spent in nutrition and secretion and some of which are eliminated from the body, while other parts, dedicated to chylification, are carried with the chyle to be blended with venous blood before this blood enters the heart; a brief observation, then, should be made here about chylification.

LXXI. The foods (as aforesaid), having been worn down and blended, divided, and thinned out, with saliva and mucus, and again blended with pancreatic juice and the two biles, and agitated by the continuous action of breathing and peristaltic movement, are thus divided, thinned out, mixed up, and to a great extent reduced to a milky fluid called chyle; this chyle, having been received here into the openings of the lacteal vessels, and having been pushed through them by peristaltic movement and diluted by lymph-fluid, and having moved into the receptacle of the chyle, flows through the thoracic duct into the left subclavian vein; and having gradually blended with blood there, it goes down with it through the vena cava into the auricle and from here into the heart's right ventricle.

LXXII. Thus the blood, having been sent out through the entire body, after being deprived of its various parts but having reacquired the greater portion of them, and having blended with nutritious chyle to remedy its deficiencies, goes back again into the heart. But so that the blood may here be suited to perform the same course, it is necessary that those lymph and chyle juices blend very closely with it and be unified and modified in order to renew its crasis with thoroughness.

LXXIII. And so, this blood contained in the heart's right ventricle, having been pushed out by its systole through the pulmonary artery in the same manner as through the aorta, is carried with a fairly strong force into the tiny, branch-shaped, elastic, capillary tubes of the lungs, and from here it is received in similar venous vessels, to be handed over, through their larger trunks, into the heart's left auricle.

LXXIV. To promote this swift flow of the blood through the admirably branch-shaped, vascular substance of the lungs, the alternating activity of breathing in and breathing out is entirely necessary, which activity, first by permitting a free flowing into elastic, expanding vessels and then by forcing the fluid out through veins which carry it off, creates a free circulation; it thoroughly shakes up the sticky items and the larger molecules and, in its passage through the twistings and turnings of the tiny cylindrical tubes, it blends, squeezes together, gives a formation to, as it were, and modifies the blood and the transformable chyle.

LXXV. That air and blood should mix together in the lungs or have any direct contact is quite at variance with all reckoning and observation.

The only demonstration of this is a florid color, which is considered to be the result of a blending and an attrition, due to their being shaken up together.

LXXVI. Another result which occurs here in the blood is the generation of heat; although this generation may be produced also in other parts of the body, still, in order that all of its needs, to a large degree indeed, may be met here, these needs must induce a result which is in proportion to what is considered necessary; for when we see that there occur in the lungs a blending, a thorough shaking, and a breakdown of diverse substances, as well as the tension and friction of blood globules and the elastic walls of the vessels, a great action necessarily follows therefrom, as well as a chemical and mechanical reaction; hence come the heat and those things which follow from it and they, through the very broad expansion of the blood there and the remarkable application of a colder medium, are completely moderated and nicely restricted.

The terrible results which the excessive heat of this medium effects in the blood can be seen from the experiment on a dog conducted by the distinguished Boerhaave.[36]

LXXVII. The blood restored in the pulmonary circulation, having been received from the veins into the left auricle of the heart, passing from here into its ventricle (the point where we started) at the time of diastole, crowns its great circulation with completeness; and, being immediately prepared to strike out, tirelessly, upon the same varied and marvelously involved journey, it proceeds.

LXXVIII. As the blood is continually being used up, not only in the performance of its tasks but also by its very nature and constitution and would be, if left to its own inevitable fate, swiftly destroyed, it must then be re-supplied constantly by matter suitable for making up for its losses.

Since, however, the body's power to make blood, that is, its assimilatory power, is severely limited with respect to the capacity of its operation, it is, hence, necessary that this matter which will cause renewal contain not only all of the blood's elements but that these elements be blended and combined in a definite fashion and that they be endowed with the required forms and qualities so that this matter may be obedient to the animal instruments and the assimilatory operation.

Thus the raw juice of earth cannot be changed into our blood, although vegetables formed from it become entirely suitable to this purpose; also animal substances are rendered unsuitable for circulation, even in a state of putrification, which is harmful to the blood's constitution; but after being completely dissolved by rotting and destroyed and scattered into air and earth, they again mix in the vessels of vegetables, combine into appropriate new forms, and prepare to enter into a compounding of animal liquids: thus are the very nice circulations of the macrocosm accomplished.

LXXIX. A food which is, perhaps, very useful to the human race and which from our body structure appears to have been intended for us is the fruit or seed of grain; foods of this type are bland, viscid, softening, endowed with no pungent salt or aromatic stimulating oil, but are formed from rather mild components, which are tasteless, saponaceous-viscid, earthy-saline, and joined to bland, oily parts.

They soften and swell up in water and are hardly ever dissolved, except in boiling water, where they are resolved into a viscid mucilage and unite a gelatinous consistency to a large amount of water.

Although grain seeds can provide a food fitting enough for a strong, active person, yet for someone not used to them or someone more delicate they are found to be too viscid and refractory, unless prepared by the due operation (*encherise*) of fermentation and cooking.

Through the fermentation of vegetable substances the saline parts, which are hidden and concealed among their oily-earthy parts as though within an enclosure, are extricated by this operation and activated; in this way the thicker, oily-earthy parts are rejected and, in the form of dregs, precipitated, while the other parts, floating on the surface, become thinner and more soluble and lose much of their firmness.

Therefore, food seeds, as they enter upon some stage of the fermentation process in the preparation of bread, become easier to divide and mold and become better suited to being subjected to chyle-producing forces and to being assimilated into good blood.

One wonders whether an alimentary juice may be modified into one blood compound from which all other compositions might be continually produced either by concretion or division, or whether nature may choose and apply (etc.) from chyle as from a chaos its various different particles, which are very similar to the parts of the blood to be renewed and which are ideally suited to their purpose. Is this an assimilatory transmutation which cannot be accomplished except with previously existing blood or its rudiments?

And is not an increase or multiplication achieved through the accretion and completion of two parts of a particle of blood which has divided into two whole particles, which are similar to the original divided particle? Hence, the more the body abounds in good blood, the more abundant is the amount of food which is assimilated into blood, and vice versa.

LXXX. So that the blood may be kept in balance and a free circulation fostered, an appropriate condition of solids is required; for, as the blood nourishes and sustains solids, it is in this way prepared, modified, and sustained by the solids, which mutually interact in such a way that, if the blood affects one solid in some abnormal fashion, it also affects a second solid; and thus they bring about illness.

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[36] See Hermann Boerhaave, *Elements of Chemistry*, [trans. T. Dallowe, (2 v., London, 1735), 1: pp. 162–165. Boerhaave's experiment is also described at length in Stephen Hales's *Statical Essays: Containing Haemastaticks*, (2 v., London, 1733), 2: pp. 102–104.

LXXXI. When the altered blood acts upon the solids in an unusual manner, so that the solids, altered in their actions, will reproduce the new effect upon the already-affected blood, this action and reaction can be so increased and multiplied among the solids that, as a result, the worst possible misfortunes to the animal mechanism can follow upon a cause which is, indeed, slight.

LXXXII. Let us now consider certain bad conditions of the blood, which produce illnesses in the microcosm, in the manner stated (LXXX).

The first failing which we shall point out is merely a superfluity of its own quality, almost without change in it or the addition of heterogeneous, illness-inducing matter: namely, an excessive proportion of blood in relation to serum and its rather strong, natural coagulant force, which produces inflamed obstructions, fits of suffocation, etc.

The proximate cause is the excessively great elastic force of the solids which modify the blood when the body has been furnished with good chyle.

The treatment is to lessen the quantity of the blood, to increase the proportion of serum, and to relax the activity of the solids; this is achieved by a removal and dilution of blood; water, however, being just about the only general-purpose dilutent, is not very well able to produce the desired effect by itself; having too little the nature of serum, it does not blend closely and firmly with this blood but quickly separates from it in the lateral ducts everywhere and in the kidneys.

When the blood has been removed, a cure is best accomplished by (1) a draught of milk-serum, boiled milk[37] etc.; (2) eating boiled fruit and soft pot-herbs with honey, manna, sugar, etc.; (3) weakening, saline, saponaceous, and diluted juices, infusions, and decoctions, particularly of vegetables; (4) very watery manufactured soaps (5) resolving and weakening salts, but not those which produce excessive heat, such as niter,[38] regenerated tartar,[39] etc. (6) cathartics, which have the power to resolve the blood and loosen solids; the following are dedicated to this purpose with good results: infusions of fistular cassia[40] and fennel with cathartic salts, such as Glauber's salt,[41] bitter cathartic salt,[42] and soluble tartar;[43] to them mercurial items can sometimes be joined; (7) tepid baths. To be avoided: wines, spirituous liquors, strong or viscid food, narcotics, heat-producing items, astringents, etc.

LXXXIII. The opposite of the above-mentioned indisposition, namely, the dissolution of the blood and an excessive proportion of serous lymphatic parts produces varied and serious illnesses in the body, which are not easy to cure: such as weaknesses, fainting spells, cold, stagnations and obstructions—especially in the glands, a looseness of solids, effusions of liquids, etc.

It has these causes: large evacuations, faulty nourishment, improper manufacture of chyle, and a looseness of solids.

A cure is effected by (1) more animal foods, easy to digest, but not too great an amount, and a moderate intake of wine; (2) spicy, bitter medicines, which strengthen, produce a gentle amount of heat, and are astringent; (3) rubdowns, etc., together with moderate exercise:

Things which were required[44] in the previous case should be avoided.

LXXXIV. As almost all indispositions of blood lacking in heterogeneous matter can be referred to LXXXII or LXXXIII, let us now proceed to cases where the blood is not right, to the extent of being contaminated by heterogeneous, illness-causing matter; but those contaminations are of a very great variety and are generally unknown; we shall find acid salt to be the simplest among them, it produces as symptoms in the body: pains, obstructions, erosions, and many aberrations and malformations; it is caused by excessively acid foods or a deficiency in the production of chyle or blood.

When the blood is tainted with acid, the juices secreted from it will share the same taint; in this way the liquids intended for chylification become polluted; they become less well-suited for reducing the raw, generally acid—or readily souring—nature of foods and assimilating them into the animal nature; thus, the blood will immediately take on the raw, souring chyle; and although the body, through its blood-producing or assimilatory (etc.) power could work on this acid with mixing and combinations or eliminate it from the body, yet it is unable to do this as it labors under the present difficulty. Therefore, the harm will increase, unless the blood is supplied with more alkalescent than souring chyle.

The cure, then, is effected by (1) alkalescent food of either an animal or vegetable nature; (2) the repeated use of absorbent, cretaceous earths; in this way the acid in the chyle-producing juices will be converted into a neutral salt, which is to be eliminated through the bowels or through the urine; thus gradually through their continued use the blood can be freed from its more powerful acid; (3) alkaline, oily salts, spirit of C. C.,[45] anti-scurvy, alkalescent juices, etc.; (4) muscular movement.

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[37] Original has *lactis ebutyrati,* which is evidently a misprint. Word intended was probably *ebulliati,* here translated as boiled. The original word is used again in LXXXV.

[38] Potassium nitrate.

[39] Potassium acetate.

[40] Senna leaves.

[41] Sodium sulfate.

[42] Magnesium sulfate.

[43] Potassium tartrate.

[44] Original has *requisia,* evidently a misprinting of *requisita.*

The opposites are avoided.

LXXXV. After the acid condition there follows an alkaline condition.

Although all by itself the blood tends towards an alkaline combination, yet in the blood of a living animal there is never to be found anything truly alkaline, for nature with her foresight carefully separates parts which incline towards this disposition and eliminates them; but if nature should be prevented from carrying out her plan, because of a mistake of the secreting organs or for reasons given (LXV, 11), then this degenerating matter could, more and more, attain to a true alkaline nature; but such activity and re-activity and disturbances of such a strong quality would arise that life would swiftly perish together with vital motion; here, however, it should be noticed that a perfect alkali salt could be so mixed and blended together in a compounding of the blood that in so well-compounded a state it would elude our investigations and could produce scarcely any activity apart from the compounding of the blood: we have seen that spirit of C. C.[46] sometimes appears in a fairly large amount; and it is well known how much of acrid, alkaline vegetables can be ingested every day, which, if applied to the skin, give the strongest possible proofs of their acrid, almost caustic quality; however, when blended with animal juices and carried into the blood, they demonstrate none of the violent results which we might anticipate on the basis of their topical application; this is effected primarily by means of a preliminary blending of blood and raw viscid juices that contain within themselves something of an acid quality not yet well enough reduced to an animal nature; but, when the liquids and the blood have been completely refined and they contain nothing raw, if something of an alkaline nature were to be received into the blood, or if, with an excessive retention in the body, the liquids would begin to acquire too much of an alkalescent disposition, then, although nothing of a truly alkaline character could be demonstrated in it, nevertheless, the blood's crasis would be altered and the blood would take on an alkaline or alkalescent pollution; and this now offers an indisposition to be considered, which should be treated by its proper antidotes,[47] namely acids, vegetable and mineral, natural and acetose, properly diluted; vegetable souring food in a somewhat sparing amount but often repeated; one can also take milk, as a balsamy souring agent.

LXXXVI. If the blood were to be tainted by that excessive use of muriatic salt,[48] it would again be freed from it by an avoidance of salted things and by replenishing it with bland, diluted liquids, while, at the same time, promoting excretion of urine and feces.

LXXXVII. After the pure saline pollution there is added a pollution which is more compounded and of a more obscure nature: this matter is called a sharp, viscid and fatty substance; it is of an acid or an alkaline nature, therefore it must be carefully distinguished. This matter is, in some way, analogous to a rancid condition which we see occurring in oily, souring substances, and alkalescent ones as well.

In the blood it sometimes clings very tightly and it is not easily eradicated from the body, as it can be placed in the fat cells and can for a long time present an oozing source of offending matter.

It is caused by climate: swampy sea locations, a thick, cloudy, heavy atmosphere; by foods: moldy unfermented (etc.) bread, sharp old cheese, rancid oils, excessive indulgence in fish, old rotten salted meat; by drink: contaminated water, etc.

A cure is effected, due consideration being given to the cause and to whether the inherent tendency of the malady is of an acid or an alkaline nature: by changing one's air and regimen semi-annually; by cutting a vein, if it is indicated; with thinning juices of an alkaline-saline or an acid-saline saponaceous character and, at intervals, gentle purgatives and warming, anti-scurvy, alkalescent potions or the acid juices of vegetables; with loosening diuretics and vegetable infusions and decoctions such as herb sage, juniper-berry blossoms, and gentle dilutents; with penetrating diaphoretics,[49] antiseptics, a decoction of woods, etc.; with antimonial, sulfurous, and stimulating alteratives; with the prudent use of mercurials such as the anti-scurvy pills of the scholarly Dr. Plumber [sic];[50] finally, with medicated waters, and an intake of boiled milk[51] and serum of goat's milk, together with suitable exercise. To this also can be added glutinous fat, which can practically be treated with the same items.

LXXXVIII. The indisposition of the blood which follows is, perhaps, to be considered not so much an illness-inducing pollution as merely a faulty conformation, it owes its origin to the looseness and the inertia of the solids which modify the blood; these blood-producing organs, because of this indisposition, either innate or acquired, are not able to produce blood and are not supported by any muscular movement—they cannot effect the transformation of the softened food into the due crasis of the blood; gradually the blood will acquire from this condition the mucilaginous, viscid and inert characteristic of the foods, yet without any acrid quality.

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[45] Ammonium carbonate.

[46] Ammonium carbonate.

[47] Original has *autidotes*, a misprinting of *antidotes*.

[48] Sodium chloride.

[49] Substances that induce sweating.

[50] Andrew Plummer, professor of medicine and chemistry in the University of Edinburgh from 1726 until his death in 1755. Hutton probably attended his lectures on chemistry while a student at the university. Plummer's pill was a compound of antimony and mercury.

[51] Original has *lactis ebutyrati*, which is evidently a misprint. Word intended probably *ebulliati*, here translated as boiled.

Therefore, one should not marvel over the observation that the glands are not supplied with suitable juices by this spoiled blood and how without inflammation there arose therefrom stagnations, obstructions, and swellings, upon whose natural consequences depend the subsequent symptoms; it should not at all be expected that the bones, at the same time, ought to be supplied by an excellent, hardening nutriment from this blood which is not suitable for stronger animal concretions.

And loose fleshy fibers, which have thus been made softer and softer, aggravate the illness by increasing its causes and they cannot easily bear the force of any febrile agitation.

From these factors it is clear why babies are susceptible to this and why curing this condition is difficult when the illness has advanced a good bit.

Therefore, in effecting a cure one must proceed very cautiously in accordance with the degree of the illness; these measures are taken:

Substituting softening, watery food for cooked meat and a moderate indulgence in good wine and exercise, to the extent of its being agreeable to one's strength.

Aromatics, attenuants, cardiacs, gently stimulating and warming diuretics; saline-oily-volatile diaphoretics; antimonial sulfurs; decoctions, strengthening, somewhat astringent, and bitter extracts, quinine, a chalybeate,[52] and Ens Veneris.[53]

Sometimes a gentle emetic or cathartic of rhubarb mixed with something warm and spicy can be administered, not so much for the sake of evacuation as to stimulate the intestinal fibers, to promote the rejection of viscid mucilent, and to provide for movements and due elasticity; sulfurous mineral waters of a slightly astringent quality are applied here.

LXXXIX. To this simple malformation of the blood sometimes there can be further added something acrid or some morbid poison, which makes the illness more malignant; it can be contracted in this case as it is perhaps more easily maintained and less easily expelled than from healthy blood, or it is a matter of heredity; for in this fashion scrofula are very frequently propagated.

In this case, therefore, the treatment should vary in a certain way from the previous one, inasmuch as the specific items may find a place here; among other items, decoctions of lignum vitae liquors, sassafras, etc. are generally beneficial, together with calx water;[54] antiseptics which are balsamy and especially antimonial sulfurs, and natural as well as manufactured mineral waters, and baths in the same waters.

XC. Often the blood is infected with a noxious liquid, which can be called a purulent contamination; it has, as a cause, some manifest or hidden suppuration, an ulcer, caries, or a similar illness-causing source, whereby the infection is supplied to the blood with a daily absorption; hence there follow hectic fevers and weakening crises, which are often concluded with excessively liquid diarrhea, that is, through the working of provident nature, which diligently expels illness-causing matter: with regard to treatment, removal of the source of contamination would appear to be the first step; to carry this out, a good blood-condition is often found to be so necessary that the cause of the illness can in no way be cured before a bland, balsamy character is restored to the spoiled blood.

(1) A cure is effected especially through a strict regimen with the avoidance of anything acrid and stimulating; with bland, softening, balsamy food in small amounts but often repeated, so that slight fevers will not be caused as well as critical debilitating evacuation; paucity of nourishment is also very conducive to reducing the purulent source, but care should be taken that not even there the gentle, balsamy nature of the fluids be in any way violated:

(2) By the evacuation of the offending matter, not with sweat, which weakens too much, but by promoting lively perspiration;

Also urine, by promoting drink which is agreeable to it:

Cathartics loosen the blood too much and induce diarrhea.

And finally by fortifying with balsamy anodynes and, if on account of the virulence of the pus gangrenous conditions should threaten, by administering balsamy antiseptics.

XCI. But in order to put an end now to this dissertation, let us merely make a brief mention of the blood's most complex indispositions, which are as obscure as possible; namely, the fever-causing contamination or "febrific," as it is properly called, and other harmful conditions which do not necessarily produce a fever.

(1) They have as a proximate cause the proper substance of animal humors, corrupted by too long a retention in the body or by a faulty blending.

(2) Heterogeneous matter taken into the blood by way of nourishment or breathed in and absorbed:

The nature and the characteristics of this infecting matter are known or unknown; the former can be put into the above-mentioned categories and they are simple, with variations, or compounded or perhaps they are of another, new nature, in which all the poisonous properties of the known nature are included

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[52] Any water impregnated with iron.

[53] A medicine consisting of copper chlorides and ammonium chloride.

[54] Limewater, a solution of calcium hydroxide.

—which must be treated with the appropriate medicines, always in accordance with their particular character; but the latter, constituting much the greater part, can be further subdivided; (A) into those where, although the illness-causing matter is unknown, still, when the present effects or symptoms have been examined and thoroughly studied, the future developments can be determined, either in part or completely: or (B) where we have no knowledge of either sort.

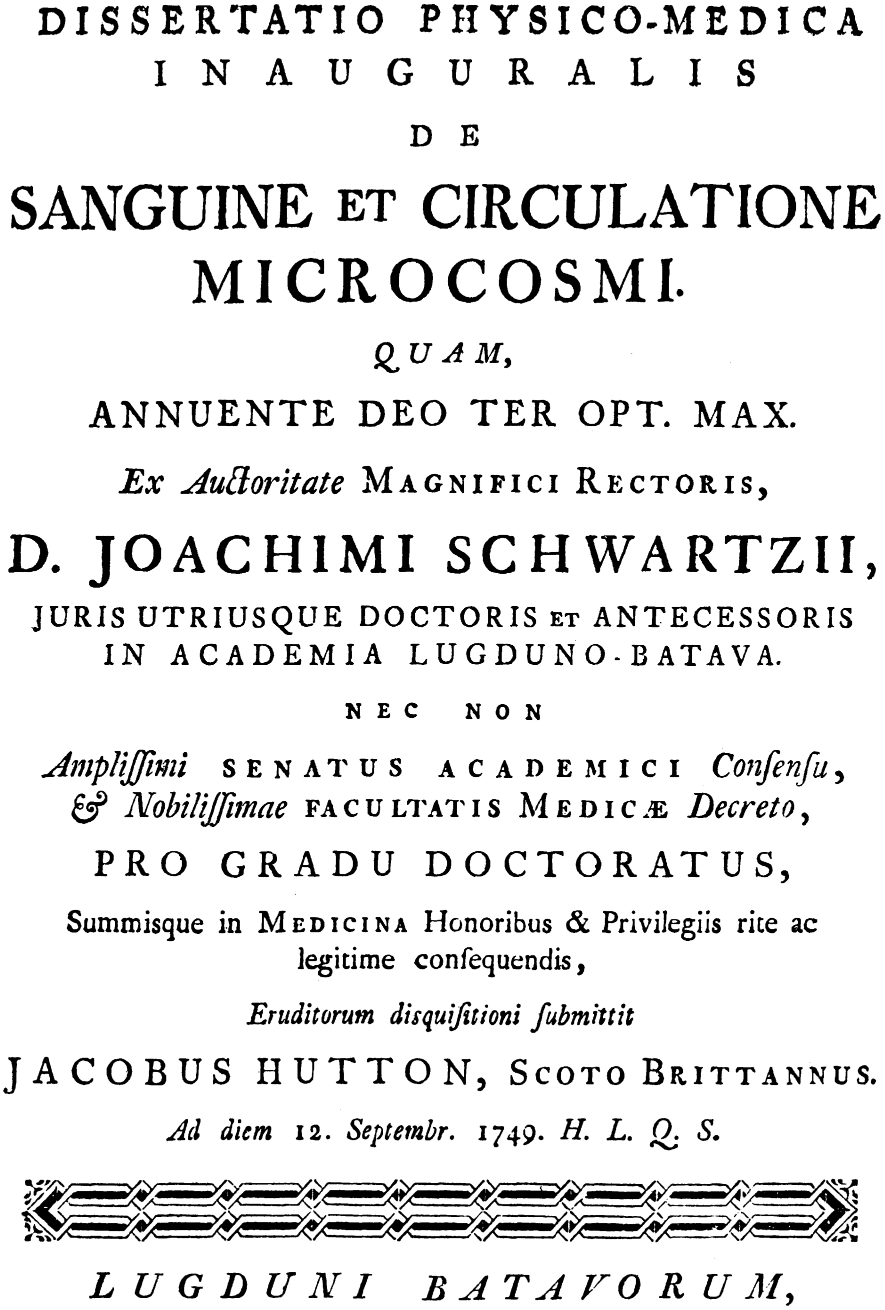
In this last case we can administer nothing except what the immediately present symptoms indicate and thus we always diligently avoid upsetting nature in her praise-worthy intentions; however, by aiding her appropriately, we might frequently be able to make progress towards her salutary goals and, sometimes, to furnish similar ones.

And in those described in (A), one may proceed further, namely, by judicious reasoning and analogic comparison, as do those who in similar situations make statements about facts known and confirmed by well-constructed experiments, due consideration always being given to the symptoms and the present conditions.

But when as many as possible of these bad, varied, and diverse factors attack the microcosm and when in one and the same sick person not just one or a second one may be found, but often they are many and in combination and loaded with various secondary symptoms, then we should arrive at a recognition of them as quickly as possible by distinguishing the genuine character of the illness and its primary symptoms; this is the work which crowns the temples of the true sons of Apollo.

As I go up onto this steep step, with an honorable, burning hunger for this distinguished award, I resolve to dedicate my time in the future and to expend my strength, however slight, with complete concentration, in avoiding, always and zealously, the wrong course of Phaethon and his unfortunate straying: with the approval of the Most High Godhead, to whom be praise and glory forever.

THE END



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JACOBUS HUTTON, SCOTO BRITTANNUS.
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EXCELLENTISSIMIS, CELEBERRIMIS,
DOCTISSIMIS ATQUE EXPERIENTISSIMIS.

VIRIS.

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MEDICINÆ DOCTORIBUS.

COLLEGII REGII MEDICORUM
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HASCE
STUDIORUM SUORUM PRIMITIAS
IN MONUMENTUM
DEBITI CULTUS ET HONORIS
D. D. D.
JACOBUS HUTTON.

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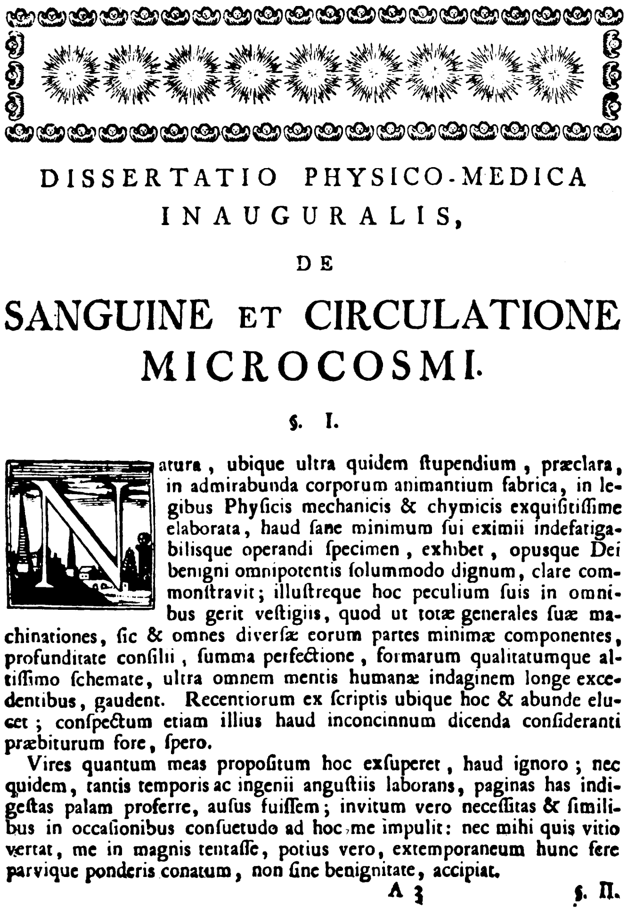
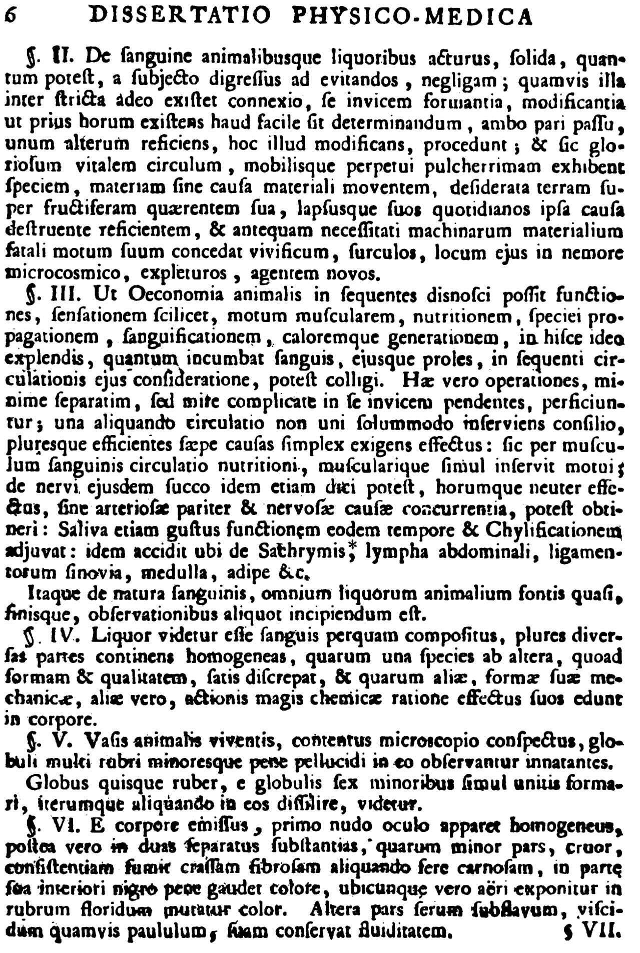


DISSERTATIO PHYSICO-MEDICA
INAUGURALIS,
DE
SANGUINE ET CIRCULATIONE MICROCOSMI.

§. I.

Natura, ubique ultra quidem ſtupendium, præclara, in admirabunda corporum animantium fabrica, in legibus Phyſicis mechanicis & chymicis exquiſitiſſime elaborata, haud ſane minimum ſui eximii indefatigabilisque operandi ſpecimen, exhibet, opusque Dei benigni omnipotentis ſolummodo dignum, clare commonſtravit; illuſtreque hoc peculium ſuis in omnibus gerit veſtigiis, quod ut totæ generales ſuæ machinationes, ſic & omnes diverſæ eorum partes minimæ componentes, profunditate conſilii, ſumma perfectione, formarum qualitatumque altiſſimo ſchemate, ultra omnem mentis humanæ indaginem longe excedentibus, gaudent. Recentiorum ex ſcriptis ubique hoc & abunde elucet; conſpectum etiam illius haud inconcinnum dicenda conſideranti præbiturum fore, ſpero.

Vires quantum meas propoſitum hoc exſuperet, haud ignoro; nec quidem, tantis temporis ac ingenii anguſtiis laborans, paginas has indigeſtas palam proferre, auſus fuiſſem; invitum vero neceſſitas & ſimilibus in occaſionibus conſuetudo ad hoc me impulit: nec mihi quis vitio vertat, me in magnis tentaſſe, potius vero, extemporaneum hunc fere parvique ponderis conatum, non ſine benignitate, accipiat.



§. II. De ſanguine animalibusque liquoribus acturus, ſolida, quantum poteſt, a ſubjecto digreſſus ad evitandos, negligam; quamvis illa inter ſtricta adeo exiſtet connexio, ſe invicem formantia, modificantia ut prius horum exiſtens haud facile ſit determinandum, ambo pari paſſu, unum alterum reficiens, hoc illud modificans, procedunt; & ſic glorioſum vitalem circulum, mobilisque perpetui pulcherrimam exhibent ſpeciem, materiam ſine cauſa materiali moventem, deſiderata terram ſuper fructiferam quærentem ſua, lapſusque ſuos quotidianos ipſa cauſa deſtruente reficientem, & antequam neceſſitati machinarum materialium fatali motum ſuum concedat vivificum, ſurculos, locum ejus in nemore microcoſmico, expleturos, agentem novos.

§. III. Ut Oeconomia animalis in ſequentes disnoſci poſſit functiones, ſenſationem ſcilicet, motum muſcularem, nutritionem, ſpeciei propagationem, ſanguificationem, caloremque generationem, in hiſce ideo explendis, quantum incumbat ſanguis, ejusque proles, in ſequenti circulationis ejus conſideratione, poteſt colligi. Hæ vero operationes, minime ſeparatim, ſed mite complicate in ſe invicem pendentes, perficiuntur; una aliquando circulatio non uni ſolummodo inſerviens conſilio, pluresque efficientes ſæpe cauſas ſimplex exigens effectus: ſic per muſculum ſanguinis circulatio nutritioni, muſcularique ſimul inſervit motui; de nervi ejusdem ſucco idem etiam dici poteſt, horumque neuter effectus, ſine arterioſæ pariter & nervoſæ cauſæ concurrentia, poteſt obtineri: Saliva etiam guſtus functionem eodem tempore & Chylificationem adjuvat: idem accidit ubi de Sathrymis* lympha abdominali, ligamentorum ſinovia, medulla, adipe &c.

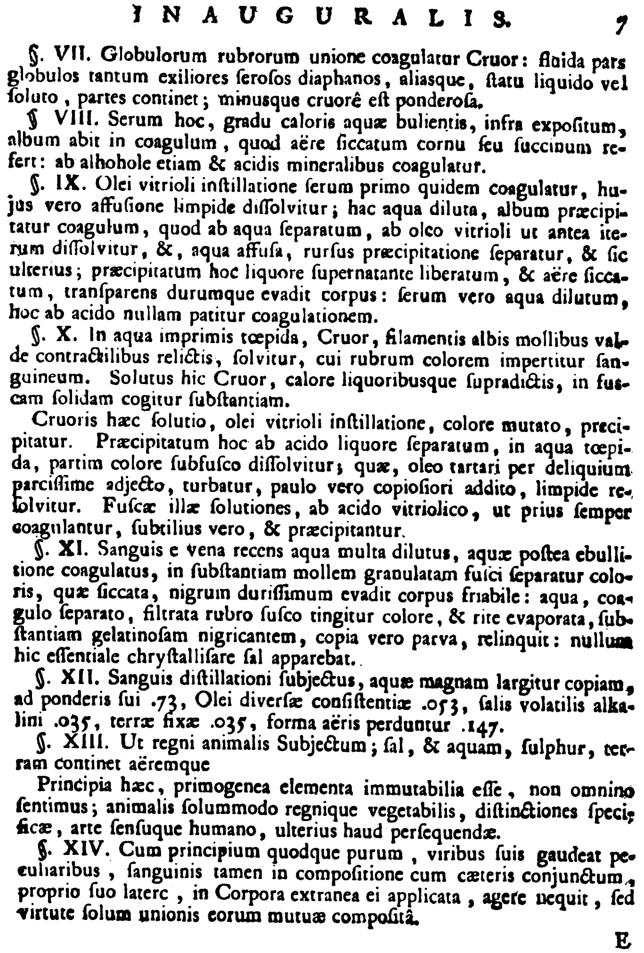
Itaque de natura ſanguinis, omnium liquorum animalium fontis quaſi, finisque, obſervationibus aliquot incipiendum eſt.

§. IV. Liquor videtur eſſe ſanguis perquam compoſitus, plures diverſas partes continens homogeneas, quarum una ſpecies ab altera, quoad formam & qualitatem, ſatis diſcrepat, & quarum aliæ, formæ ſuæ mechanicæ, aliæ vero, actionis magis chemicæ ratione effectus ſuos edunt in corpore.

§. V. Vaſis animalis viventis, contentus microscopio conſpectus, globuli multi rubri minoresque pene pellucidi in eo obſervantur innatantes.

Globus quisque ruber, e globulis ſex minoribus ſimul unitis formari, iterumque aliquando in eos diſſilire, videtur.

§. VI. E corpore emiſſus, primo nudo oculo apparet homogeneus, poſtea vero in duas ſeparatus ſubſtantias, quarum minor pars, cruor, conſiſtentiam ſumit craſſam fibroſam aliquando fere carnoſam, in parte ſua interiori nigro pene gaudet colore, ubicunque vero aëri exponitur in rubrum floridum mutatur color. Altera pars ſerum ſubflavum, viſcidum quamvis paululum, ſuam conſervat fluiditatem.



§. VII. Globulorum rubrorum unione coagulatur Cruor: fluida pars globulos tantum exiliores ſeroſos diaphanos, aliasque, ſtatu liquido vel ſoluto, partes continet; minusque cruorê eſt ponderoſa.

§ VIII. Serum hoc, gradu caloris aquæ bulientis, infra expoſitum, album abit in coagulum, quod aëre ſiccatum cornu ſeu ſuccinum refert: ab alhohole etiam & acidis mineralibus coagulatur.

§. IX. Olei vitrioli inſtillatione ſerum primo quidem coagulatur, hujus vero affuſione limpide diſſolvitur; hac aqua diluta, album præcipitatur coagulum, quod ab aqua ſeparatum, ab oleo vitrioli ut antea iterum diſſolvitur, &, aqua affuſa, rurſus præcipitatione ſeparatur, & ſic ulterius; præcipitatum hoc liquore ſupernatante liberatum, & aëre ſiccatum, tranſparens durumque evadit corpus: ſerum vero aqua dilutum, hoc ab acido nullam patitur coagulationem.

§. X. In aqua imprimis tœpida, Cruor, filamentis albis mollibus valde contractilibus relictis, ſolvitur, cui rubrum colorem impertitur ſanguineum. Solutus hic Cruor, calore liquoribusque ſupradictis, in fuſcam ſolidam cogitur ſubſtantiam.

Cruoris hæc ſolutio, olei vitrioli inſtillatione, colore mutato, precipitatur. Præcipitatum hoc ab acido liquore ſeparatum, in aqua tœpida, partim colore ſubfuſco diſſolvitur; quæ, oleo tartari per deliquium parciſſime adjecto, turbatur, paulo vero copioſiori addito, limpide reſolvitur. Fuſcæ illæ ſolutiones, ab acido vitriolico, ut prius ſemper coagulantur, ſubtilius vero, & præcipitantur.

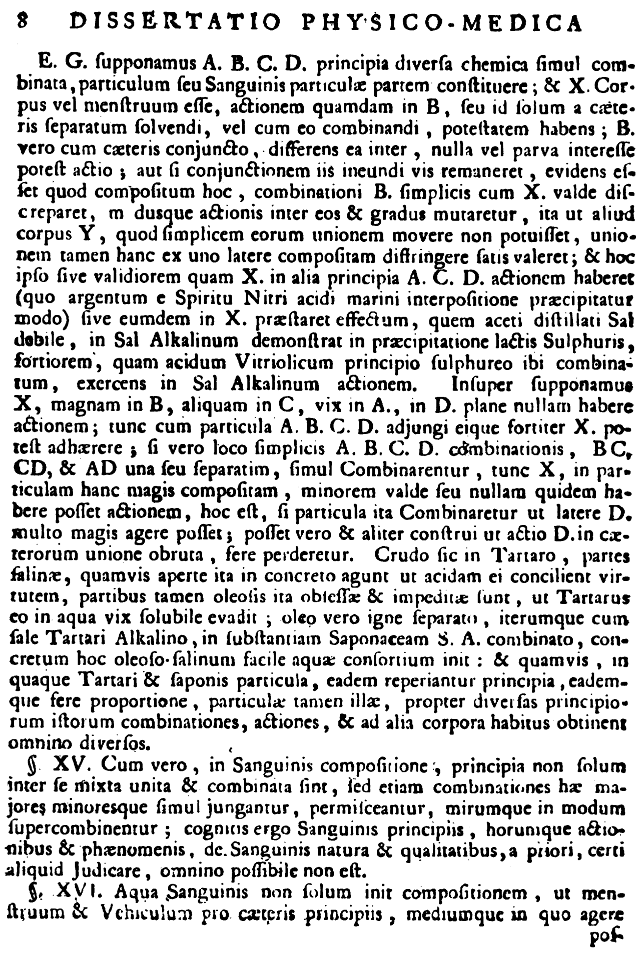
§. XI. Sanguis e vena recens aqua multa dilutus, aquæ poſtea ebullitione coagulatus, in ſubſtantiam mollem granulatam fuſci ſeparatur coloris, quæ ſiccata, nigrum duriſſimum evadit corpus friabile: aqua, coagulo ſeparato, filtrata rubro fuſco tingitur colore, & rite evaporata, ſubſtantiam gelatinoſam nigricantem, copia vero parva, relinquit: nullum hic eſſentiale chryſtalliſare ſal apparebat.

§. XII. Sanguis diſtillationi ſubjectus, aquæ magnam largitur copiam, ad ponderis ſui .73, Olei diverſæ conſiſtentiæ .053, ſalis volatilis alkalini .035, terræ fixæ .035, forma aëris perduntur .147.

§. XIII. Ut regni animalis Subjectum; ſal, & aquam, ſulphur, terram continet aëremque

Principia hæc, primogenea elementa immutabilia eſſe, non omnino ſentimus; animalis ſolummodo regnique vegetabilis, diſtinctiones ſpecificæ, arte ſenſuque humano, ulterius haud perſequendæ.

§. XIV. Cum principium quodque purum, viribus ſuis gaudeat peculiaribus, ſanguinis tamen in compoſitione cum cæteris conjunctum, proprio ſuo latere, in Corpora extranea ei applicata, agere nequit, ſed virtute ſolum unionis eorum mutuæ compoſitâ.



E. G. ſupponamus A. B. C. D. principia diverſa chemica ſimul combinata, particulum ſeu Sanguinis particulæ partem conſtituere; & X. Corpus vel menſtruum eſſe, actionem quamdam in B, ſeu id ſolum a cæteris ſeparatum ſolvendi, vel cum eo combinandi, poteſtatem habens; B. vero cum cæteris conjuncto, differens ea inter, nulla vel parva intereſſe poteſt actio; aut ſi conjunctionem iis ineundi vis remaneret, evidens eſſet quod compoſitum hoc, combinationi B. ſimplicis cum X. valde diſcreparet, modusque actionis inter eos & gradus mutaretur, ita ut aliud corpus Y, quod ſimplicem eorum unionem movere non potuiſſet, unionem tamen hanc ex uno latere compoſitam diſtringere ſatis valeret; & hoc ipſo ſive validiorem quam X. in alia principia A. C. D. actionem haberet (quo argentum e Spiritu Nitri acidi marini interpoſitione præcipitatur modo) ſive eumdem in X. præſtaret effectum, quem aceti diſtillati Sal debile, in Sal Alkalinum demonſtrat in præcipitatione lactis Sulphuris, fortiorem, quam acidum Vitriolicum principio ſulphureo ibi combinatum, exercens in Sal Alkalinum actionem. Inſuper ſupponamus X, magnam in B, aliquam in C, vix in A., in D. plane nullam habere actionem; tunc cum particula A. B. C. D. adjungi eique fortiter X. poteſt adhærere; ſi vero loco ſimplicis A. B. C. D. combinationis, BC, CD, & AD una ſeu ſeparatim, ſimul Combinarentur, tunc X, in particulam hanc magis compoſitam, minorem valde ſeu nullam quidem habere poſſet actionem, hoc eſt, ſi particula ita Combinaretur ut latere D. multo magis agere poſſet; poſſet vero & aliter conſtrui ut actio D. in cæterorum unione obruta, fere perderetur. Crudo ſic in Tartaro, partes ſalinæ, quamvis aperte ita in concreto agunt ut acidam ei concilient virtutem, partibus tamen oleoſis ita obleſſæ & impeditæ ſunt, ut Tartarus eo in aqua vix ſolubile evadit; oleo vero igne ſeparato, iterumque cum ſale Tartari Alkalino, in ſubſtantiam Saponaceam S. A. combinato, concretum hoc oleoſo-ſalinum facile aquæ conſortium init: & quamvis, in quaque Tartari & ſaponis particula, eadem reperiantur principia, eademque fere proportione, particulæ tamen illæ, propter diverſas principiorum iſtorum combinationes, actiones, & ad alia corpora habitus obtinent omnino diverſos.

§ XV. Cum vero, in Sanguinis compoſitione, principia non ſolum inter ſe mixta unita & combinata ſint, ſed etiam combinationes hæ majores minoresque ſimul jungantur, permiſceantur, mirumque in modum ſupercombinentur; cognitis ergo Sanguinis principiis, horumque actionibus & phænomenis, de Sanguinis natura & qualitatibus, a priori, certi aliquid Judicare, omnino poſſibile non eſt.

§. XVI. Aqua Sanguinis non ſolum init compoſitionem, ut menſtruum & Vehiculum pro cæteris principiis, mediumque in quo agere poſ poſſint, fluiditatis ejus Baſin conſtituens ſed etiam Combinationes eorum minutas ſolidas ſubit mixtionesque fere primarias.

§. XVII. Aquæ naturam, proprietatesque peculiares enarrandi non eſt hic locus, ut ibi, quod ubique, idem ſimplex invenitur elementum; & quanquam diverſas in combinationibus patitur modificationes nullam nominis diverſitatem ſortitur, & fere ſemper natura ſua diſtinctiſſima iterum ſeparatur.

§. XVIII. Terra, ſpeculationis anſam præbet tam difficilem, tantaque caligine obrutam, ut certe haud temere ſuſcipienda ſit; quanto minus, infirmo ingenio meo paucisque hanc circa experimentis adornato, aptum debet cenſeri? exoptandum quidem eſt hac in re lucis aliquid productum eſſe; hactenus vero ſubjecti ſterilitas, naturaque obſcura, Chemicos aut ab eo deterruit, aut eos, ut illud, pro aliqua re phænominis ſplendidiori, negligerent, inclinavit, hujusque defectus multam mixtionis Chymicæ corporum procreat ignorantiam: '& terræ hujus cognitioni, maximum objicit obſtaculum, definitio ejus vel idea obſcura, deficiens, duobus tantum negativis paſſivis quaſi conſiſtens.

§. XIX. Ut huic principio Characteriſticum eſt igni & aquæ reſiſtere, ſic terra calcinatione & edulcoratione Capitis mortui in diſtillatione Sanguinis oleorumque ejus rectificatione relicti, impetrata, pro hoc principio vulgo exhibita eſt; Hoc vero haud paulo ſub dubio laborare ſentio; potiusque forſan Conbinationem quandam fortiſſimam inter hanc & ſalinum principium, debere æſtimari, quâ actiones earum priores deſtruuntur quaſi, ſeu impediuntur.

Talem forte contingere Synchryſin videmus, repetita calcinatione, ſolutione & evaporatione Salis Alkalini fixi, quâ pars diſperit, pars in terram fixam inertem huic ſimilem convertitur: Fateor veriſimile hic videri, principium ſalinum a cohæſione liberatum avolare, dum pura relinquitur terra; ſed quamobrem actionem ſuam combinatoriam tam multum eo infractum habet? quod nunquam niſi Synchryſe contingere videmus.

Si vero, characteribus naturaque nobis immutabili judicaretur principium, tunc multa corpora valdeque diſcrepantia dignitatem hanc æquo jure poſcentia reperirentur; & hoc quidem reſpectu, creta Anglicana terræ huic, nihil principii cederet qualitate.

Multa ſunt experimenta, hanc principii ſalini actionis enervationem combinatione, illuſtrantia; ut olei Vitrioli & Salis Alkali ſaturatio; certe haud invenitur corpus quod ab uno vel altero quodammodo ſolvi nequeat; juncta vero, corpus producunt, quod loco cum aqua actionis, quam prius ambo habebant fortiſſimam, haud adeo nunc ab illa facile diſſolvitur, actionem cum ea ſaltem ſatis habet limitatam; nec in ullum aliud agit Corpus, niſi, quod continet, aquei inflammabilisque ratione principii. Exemplum aliud ſcopo noſtro ſpectantius ſuppeditat vitri formatio, ubi notandum eſt Sal fixum Alkalinum activum, in unione cum terra noſtra animali, (multo minus activa, acidis autem ſolubilis) ſtatum adipiſci, quo magis paſſivum forte nullum habetur corpus.

Sed quid ſentiendum de terra copioſa producta combinatione acidi puri Vitriolici cum Alkohole ubi certe nulla exiſtit; nonne probat hoc magis terræ a ſale compoſitionem quam vice verſa? Niſi terra ſub intelligatur ſalina; qui loquendi modus damnum ſcientiæ, ideas confundento*, affert plurimum, poteſt ne itaque principium hoc terreſtre e ſalino confluri?#Nonne lucem hoc multis eorum abſtruſis afferet phenomenis?

Quam terreſtrem principii ſalini Combinationem maxime probat ſubſequens experimentum; nempe calcem vivam acido Vitriolico ſaturando, quo minime diſſolvitur, effervesſcentia vero & Calore multo, ſimul ſociantur; maſſa hac igne aperto bene calcinata duplum fere habet pondus calcis; quamvis vero tanta inſit ſalini portio, (ut ſalinam calcis ipſius naturam ſilentio prætereamus) ſub forma tamen terræ inertis apparet, nec ullum indolis ſalinæ vel minimum demonſtrat ſignum; in aqua, acido Vitrioli & aceti intactum fere manet, in Spiritu Nitri ſolvitur quodammodo, ſed difficillime. Ad propoſitum vero ut redeam.

XX. Per terram, Sanguinis principium, corpus intelligimus per ſe fixum & aquâ inſolubile, magnam affinitatem & actionem habens cum principio ſalino cujus ope ſolubile in aqua redditur & cum aliis miſcetur corporibus: in ſale Alkalino invenitur intime cum principio Salino & aqua forſan combinata; combinatio hæc ulterius materia Sulphurea ſeu oleoſa ſociata, Alkali conſtituit Volatile: in ardenti non continetur ſpiritu; omnis vero Vegetabilis oleique animalis ingreditur compoſitionem, ſemper tamen principio ſalino ſociata: eodem modo in omnibus eorum magis compoſitis ſalibus, & ſuccis, magna ſatis permiſcetur quantitate, combinationibus autem & ſuper de compoſitionibus complexiſſimis.

XXI. Sed ut idoneam haberemus notionem combinationum iſtorum terreſtrium compoſitorum, altius noſtra petenda eſſet indagatio & in regno vegetabili diligenter inſtituendo; ubi quamvis aliis principiis ſemper firmiter & intime adjuncta inveniretur; diverſas tamen ejus ſpecies in ſuccis illorum variisque ſalibus&c. ſimpliciori nunc, nunc ſtatu magis compoſito, perpendendo & comparando, de proprietatibus ejus & phænomenis quæ, conditionibus hiſce diverſis, habet erga cætera principia melius judicare poſſemus: mutationes ſic etiam circulatione animali in iis productas obſervaremus, non in eo quod elementarem ejus ut ita dicam ſeu ſtatum forte ſimpliciter mixtum ſpectat, ſed Combinationes ſolummodo ejus compoſitas, nam quamvis omnibus in vegetabilibus natura ejus ultima ſit eadem, ope tamen diverſarum ſuimetipſius cæterisque cum principiis combinationum, varias ſpecificas terras ideoque valde compoſitas producit, diverſis vegetabilibus, vel ejuſdem Plantæ ſuccis diverſis, aut ſucci denique ejuſdem partibus diverſis componentibus, peculiares; uſumque haud parvum, ad illorum ſapores, adſtringentias, aliasque proprietates modificandum, præſtantes.

XXII. Animalis autem nutritionis conſideratione, diverſorumque ſuccorum Vegetabilium in corpus animale actionum, plurimas terrarum iſtarum vegetabilium compoſitarum ſpecificarum, ad Sanguineam ſubeundum compoſitionem, ineptas omnino inveniemus; terrasque ſolummodo eorum generales magis mites oleisque blandis adunatas, quæ ſanguificationi inſerviunt, agnoſcemus; ex: gr. terra Gallarum adſtringens, Aloës purgans, Ypecacuanhæ emetica, cum Sanguinè non ſine tumultu conſequentibusque alterationibus, miſcentur; cum e contra terra dulcis (ut ita dicam) Sacchari, amice ingreditur, aliisque cum alimentis, Sanguinem belle valet ſuſtinere.

§. XXIII. Hæ terræ alimentares, mutationes ſatis magnas patiuntur in ſanguine, reſolutis fortaſſe texturis craſſioribus novisque ſubtiliſſimis mixtionibus confectis, quo ſtricte adeo intimeque cæteris cum principiis aliisque unitur partibus, ut diſtillatione ſanguinis inſtituta, magna ex parte in olei & ſalis volatilis compoſitionem aſcendit, parva quantitate relicta, quæ debita calcinatione a nitudine* ſulphurea liberata, ſub terræ puræ homogeneæ invenitur ſpecie, pulvis præbens terreum album fixiſſimum inſipidum in acidis vegetabilibus, ſolutu difficile, niſi acidi mineralis ope ſubtilius reddatur.

Hæc terra conſiſtentiæ & formæ Baſis, ſanguinis principium terreſtre, utpote ulterius illud ſeparare neſcimus, tenenda eſt.

§. XXIV. Sanguis non ſolum cum vegetabilibus, ſed regno etiam minerali commune habet principium ſalinum, & quidquid terrei, ſoluta ſeu liquida reperitur in forma, id ſolum hujus principii unius auxilio perficitur; & hoc verum eſt ſal acidum primogenium, a quo cætera, proles ejus magis vel minus compoſitæ, omnia oriuntur ſalia.

§. XXV. Certe non ſine cauſa chemicum exhibere principium purum haud poſſibilè habetur; ſal vero hoc acidum, niſi cum aqua, forſan ſatis immixtum, in oleo Vitrioli vel ſulphuris per Campanam bene rectificato, reperiendum eſt.

In Vegetabilibus & animalibus, cum ſubſtantia quadam ſulphurea ſeu oleoſa ſemper combinatum deprehenditur, quâ tam volatile redditur, ut una cum phlegmate aſſurgens, acidorum mineralium in modum Concentrari nequeat.

§. XXVI. Acidum hoc mixtionem ſeu Compoſitionem ſubit oleorum omnium Vegetabilium & animalium; ulterius cum terris eorum peculiaribus, oleisque conjunctum, varia illorum Compoſita eſſentialia vel naturalia efformat ſalia.

In multis horum ſalium vegetabilium, oleum non ita firmiter partibus ſalinis terreſtribusque aduncțum eſt, ut non deſtillatione ab iis ſeparetur, relicta materia aliqua nigra oleoſa maſſæ ſalinæ leviter adhærente, carbonis in modum; oleo vero hoc, aperto igne, difflato, ſal alkali fixum relinquitur, compoſitum ut ſupra (§. XX.) obſervavimus: in ſalium vero animalium mixtione ſubſtantia hac terreo-ſalina oleum tam intime ſibi inſertum habet, ut in diſtillatione tota ſublime rapiatur, in ſalis alkali forma, ſed a ſale alkalino fixo propter Combinationem illius oleoſam valde diſcrepans.

§. XXVII Haud magna certe adeſt difficultas, indolem, & phænomena acidi & alkali, concipiendi, contraria.

Sal alkali componitur, ut ſupra obſervavimus, per Combinationem ſalini principiique terreſtris; quæ combinatio terræ actionem ſeu cum ſale acido ulterius niſum ad unionem minime impedit; ſed propter terræ hujus ſolubilitatem & facilem in mixtum hunc ſalino terreum, additum qui, hac mixtione alkaliſiciente peculiari minime ſaturante, ſali acido conciliatur, actio inter eos valida valde ſupereſt & vivia, ita ut ſtatu ſoluto mixta, impetuoſitate & ebulitione in ſe irruant & ſaturentur, hoc eſt, Compoſitum efficiunt, ulteriorem cum acido alkalive actionem Combinatoriam pariens nullam.

Combinatio hac ſaturativa, ſeu, ut dicitur, neutralis, quamvis ſatis fortis, non tamen tantâ, ut prior ſalis puri & terræ gaudet firmitate; nam ſemper quanto ſimpliciores ſint partes combinaturæ, tanto fortior Cæteris paribus, erit Combinatio; & hæc generalis in Chemia haberi poteſt regula: ſic nitri, ſalis marini & vegetabilium ſalia acida compoſita, pro cujusque viribus, plus vel minus fortiter cum ſali alkali combinantur; omnia vero acido vitrioli cedunt, quod ſimplicius, ideo fortiorem in corpus alkalinum edit actionem; corpus etiam cuprum magis compoſitum in ſpiritu acido diſſolutum, ſale alkali vel terra Cretacea ſimpliciori præcipitatur; ſed hic obſervandum eſt, hanc regulam ſolummodo fieri & applicandam eſſe quando corpora differentia in corpus commune uno eodemque agunt principio, ut exemplo acidi & alkali ſupra allato, vidimus, ubi oleum vitrioli ſpiritus nitri, ſalisque marini, &c; in corpus alkalinum agunt ex latere ſolummodo ſalino, hoc eſt, eodem acido illorum puro; aliter vero ſe res habet quando corpus ſimplicius ut argentum in ſpiritu nitri ſolutum, magis compoſito ut cupro præcipitatur corpore; hoc in caſu multæ ſunt aliæ rationes conſiderandæ; nam ſpiritus nitri in principium metallorum agit ſulphureo-terreſtre mi-

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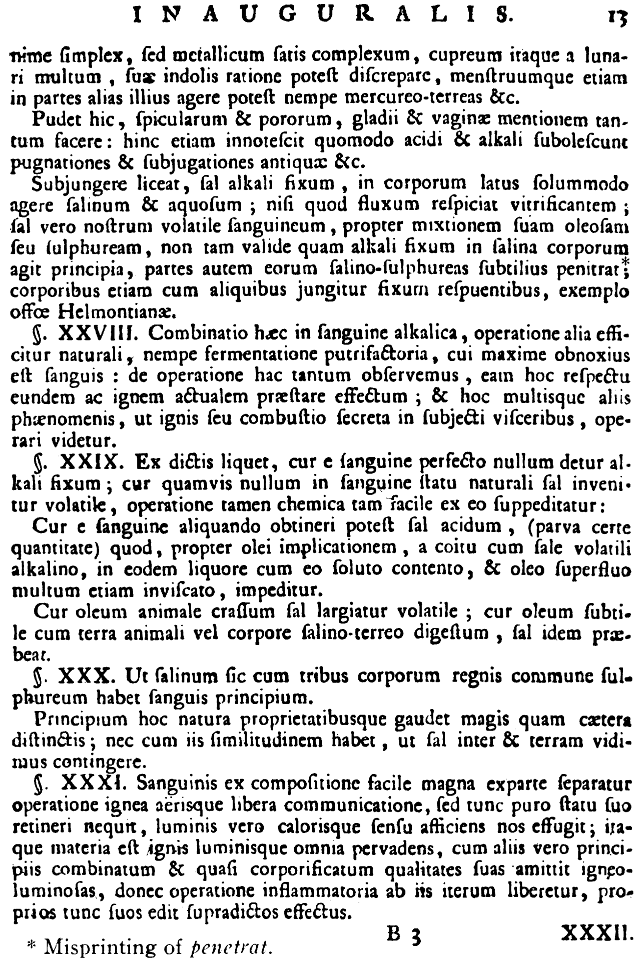
* Misprinting of *confundendo*.

# Misprinting of *conflari*.

* Sic.



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nime ſimplex, ſed metallicum ſatis complexum, cupreum itaque a lunari multum, ſuæ indolis ratione poteſt diſcrepare, menſtruumque etiam in partes alias illius agere poteſt nempe mercureo-terreas &c.

Pudet hic, ſpicularum & pororum, gladii & vaginæ mentionem tantum facere: hinc etiam innoteſcit quomodo acidi & alkali ſuboleſcunt pugnationes & ſubjugationes antiquæ &c.

Subjungere liceat, ſal alkali fixum, in corporum latus ſolummodo agere ſalinum & aquoſum; niſi quod fluxum reſpiciat vitrificantem; ſal vero noſtrum volatile ſanguineum, propter mixtionem ſuam oleoſam ſeu ſulphuream, non tam valide quam alkali fixum in ſalina corporum agit principia, partes autem eorum ſalino-ſulphureas ſubtilius penitrat*; corporibus etiam cum aliquibus jungitur fixum reſpuentibus, exemplo offœ Helmontianæ.

§. XXVIII. Combinatio hæc in ſanguine alkalica, operatione alia efficitur naturali, nempe fermentatione putrifactoria, cui maxime obnoxius eſt ſanguis: de operatione hac tantum obſervemus, eam hoc reſpectu eundem ac ignem actualem præſtare effectum; & hoc multisque aliis phænomenis, ut ignis ſeu combuſtio ſecreta in ſubjecti viſceribus, operari videtur.

§. XXIX. Ex dictis liquet, cur e ſanguine perfecto nullum detur alkali fixum; cur quamvis nullum in ſanguine ſtatu naturali ſal invenitur volatile, operatione tamen chemica tam facile ex eo ſuppeditatur:

Cur e ſanguine aliquando obtineri poteſt ſal acidum, (parva certe quantitate) quod, propter olei implicationem, a coitu cum ſale volatili alkalino, in eodem liquore cum eo ſoluto contento, & oleo ſuperfluo multum etiam inviſcato, impeditur.

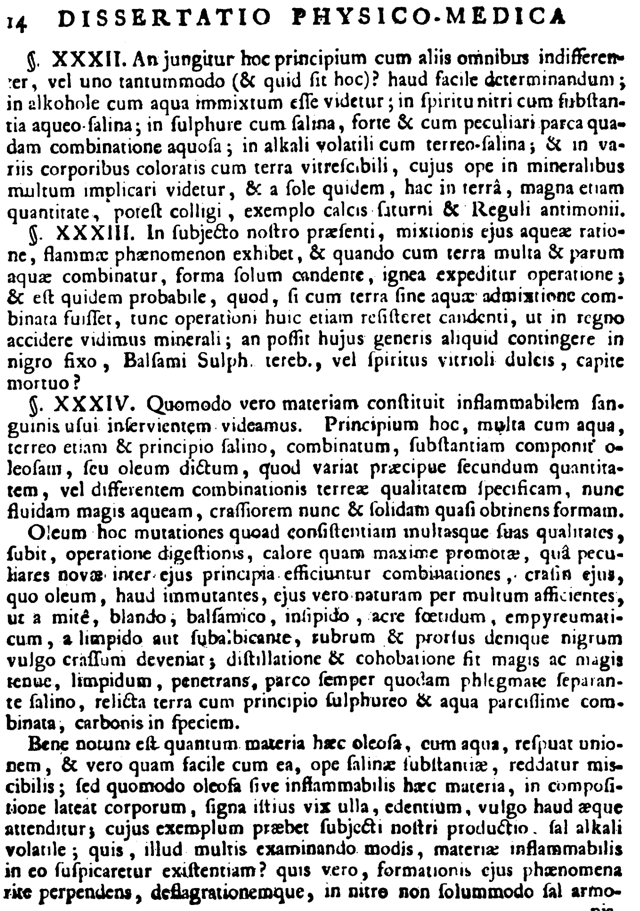
Cur oleum animale craſſum ſal largiatur volatile; cur oleum ſubtile cum terra animali vel corpore ſalino-terreo digeſtum, ſal idem præbeat.

§. XXX. Ut ſalinum ſic cum tribus corporum regnis commune ſulphureum habet ſanguis principium.

Principium hoc natura proprietatibusque gaudet magis quam cætera diſtinctis; nec cum iis ſimilitudinem habet, ut ſal inter & terram vidimus contingere.

§. XXXI. Sanguinis ex compoſitione facile magna exparte ſeparatur operatione ignea aëriſque libera communicatione, ſed tunc puro ſtatu ſuo retineri nequit, luminis vero caloriſque ſenſu afficiens nos effugit; itaque materia eſt ignis luminiſque omnia pervadens, cum aliis vero principiis combinatum & quaſi corporificatum qualitates ſuas amittit igneo-luminoſas, donec operatione inflammatoria ab iis iterum liberetur, proprios tunc ſuos edit ſupradictos effectus.

B 3 XXXII.



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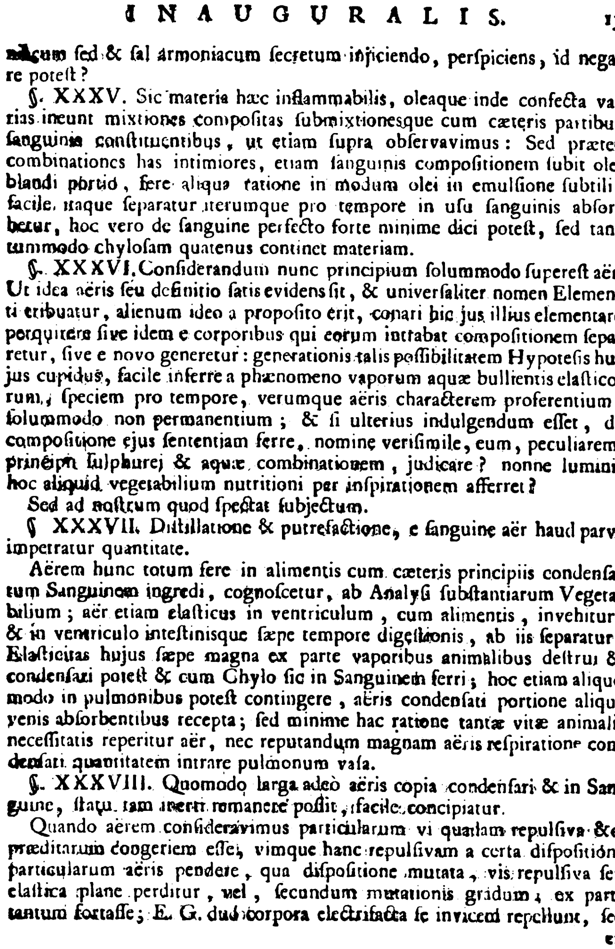
§. XXXII. An jungitur hoc principium cum aliis omnibus indifferenter, vel uno tantummodo (& quid ſit hoc)? haud facile determinandum; in alkohole cum aqua immixtum eſſe videtur; in ſpiritu nitri cum ſubſtantia aqueo-ſalina; in ſulphure cum ſalina, forte & cum peculiari parca quadam combinatione aquoſa; in alkali volatili cum terreo-ſalina; & in variis corporibus coloratis cum terra vitreſcibili, cujus ope in mineralibus multum implicari videtur, & a ſole quidem, hac in terrâ, magna etiam quantitate, poteſt colligi, exemplo calcis ſaturni & Reguli antimonii.

§. XXXIII. In ſubjecto noſtro præſenti, mixtionis ejus aqueæ ratione, flammæ phænomenon exhibet, & quando cum terra multa & parum aquæ combinatur, forma ſolum candente, ignea expeditur operatione; & eſt quidem probabile, quod, ſi cum terra ſine aquæ admixtione combinata fuiſſet, tunc operationi huic etiam reſiſteret candenti, ut in regno accidere vidimus minerali; an poſſit hujus generis aliquid contingere in nigro fixo, Balſami Sulph. tereb., vel ſpiritus vitrioli dulcis, capite mortuo?

§. XXXIV. Quomodo vero materiam conſtituit inflammabilem ſanguinis uſui inſervientem videamus. Principium hoc, multa cum aqua, terreo etiam & principio ſalino, combinatum, ſubſtantiam componit oleoſam, ſeu oleum dictum, quod variat præcipue ſecundum quantitatem, vel differentem combinationis terreæ qualitatem ſpecificam, nunc fluidam magis aqueam, craſſiorem nunc & ſolidam quaſi obtinens formam.

Oleum hoc mutationes quoad conſiſtentiam multaſque ſuas qualitates, ſubit, operatione digeſtionis, calore quam maxime promotæ, quâ peculiares novæ inter ejus principia efficiuntur combinationes, craſin ejus, quo oleum, haud immutantes, ejus vero naturam per multum afficientes, ut a mitê, blando, balſamico, inſipido, acre fœtidum, empyreumaticum, a limpido aut ſubalbicante, rubrum & prorſus denique nigrum vulgo craſſum deveniat; diſtillatione & cohobatione fit magis ac magis tenue, limpidum, penetrans, parco ſemper quodam phlegmate ſeparante ſalino, relicta terra cum principio ſulphureo & aqua parciſſime combinata, carbonis in ſpeciem.

Bene notum eſt quantum materia hæc oleoſa, cum aqua, reſpuat unionem, & vero quam facile cum ea, ope ſalinæ ſubſtantiæ, reddatur miſcibilis; ſed quomodo oleoſa ſive inflammabilis hæc materia, in compoſitione lateat corporum, ſigna iſtius vix ulla, edentium, vulgo haud æque attenditur; cujus exemplum præbet ſubjecti noſtri productio. ſal alkali volatile; quis, illud multis examinando modis, materiæ inflammabilis in eo ſuſpicaretur exiſtentiam? quis vero, formationis ejus phænomena rite perpendens, deflagrationemque, in nitro non ſolummodo ſal armo-



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niacum ſed & ſal armoniacum ſecretum inficiendo, perſpiciens, id negare poteſt?

§. XXXV. Sic materia hæc inflammabilis, oleaque inde confecta varias ineunt mixtiones compoſitas ſubmixtioneſque cum cæteris partibus ſanguinis conſtituentibus, ut etiam ſupra obſervavimus: Sed præter combinationes has intimiores, etiam ſanguinis compoſitionem ſubit olei blandi portio, fere aliqua ratione in modum olei in emulſione ſubtili, facile itaque ſeparatur iterumque pro tempore in uſu ſanguinis abſorbetur, hoc vero de ſanguine perfecto forte minime dici poteſt, ſed tantummodo chyloſam quatenus continet materiam.

§. XXXVI. Conſiderandum nunc principium ſolummodo ſupereſt aër. Ut idea aëris ſeu definitio ſatis evidens ſit, & univerſaliter nomen Elementi tribuatur, alienum ideo a propoſito erit, conari hic jus illius elementare perquirere ſive idem e corporibus qui eorum intrabat compoſitionem ſeparetur, ſive e novo generetur: generationis talis poſſibilitatem Hypoteſis hujus cupidus, facile inferre a phænomeno vaporum aquæ bullientis elaſticorum, ſpeciem pro tempore, verumque aëris characterem proferentium, ſolummodo non permanentium; & ſi ulterius indulgendum eſſet, de compoſitione ejus ſententiam ferre, nomine veriſimile, eum, peculiarem, principii ſulphurei & aquæ combinationem, judicare? nonne luminis hoc aliquid vegetabilium nutritioni per inſpirationem afferret?

Sed ad noſtrum quod ſpectat ſubjectum.

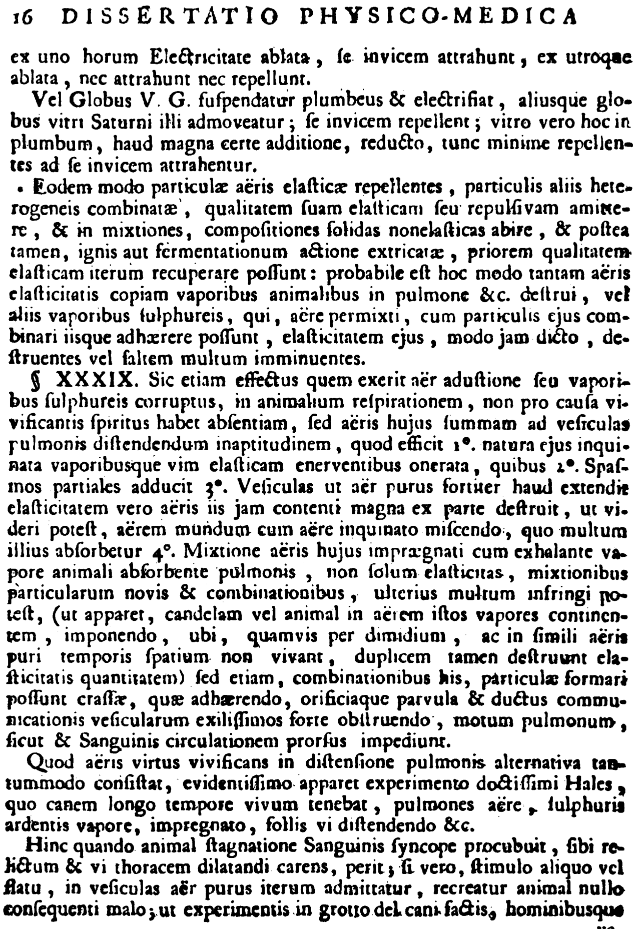
§ XXXVII. Diſtillatione & putrefactione, e ſanguine aër haud parva impetratur quantitate.

Aërem hunc totum fere in alimentis cum cæteris principiis condenſatum Sanguinem ingredi, cognoſcetur, ab Analyſi ſubſtantiarum Vegetabilium; aër etiam elaſticus in ventriculum, cum alimentis, invehitur, & in ventriculo inteſtiniſque ſæpe tempore digeſtionis, ab iis ſeparatur; Elaſticitas hujus ſæpe magna ex parte vaporibus animalibus deſtrui & condenſari poteſt & cum Chylo ſic in Sanguinem ferri; hoc etiam aliquo modo in pulmonibus poteſt contingere, aëris condenſati portione aliqua venis abſorbentibus recepta; ſed minime hac ratione tantæ vitæ animalis neceſſitatis reperitur aër, nec reputandum magnam aëris reſpiratione condenſati quantitatem intrare pulmonum vaſa.

§. XXXVIII. Quomodo larga adeò aëris copia condenſari & in Sanguine, ſtatu tam inerti remanere poſſit, facile concipiatur.

Quando aërem conſideravimus particularum vi quadam repulſiva &c. præditarum congeriem eſſe, vimque hanc repulſivam a certa diſpoſitione particularum aëris pendere, qua diſpoſitione mutata, vis repulſiva ſeu elaſtica plane perditur, vel, ſecundum mutationis gradum, ex parte tantum fortaſſe; E. G. duo corpora electrifacta ſe invicem repellunt, ſed

ex



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ex uno horum Electricitate ablata, ſe invicem attrahunt, ex utroque ablata, nec attrahunt nec repellunt.

Vel Globus V. G. ſuſpendatur plumbeus & electrifiat, aliusque globus vitri Saturni illi admoveatur; ſe invicem repellent; vitro vero hoc in plumbum, haud magna certe additione, reducto, tunc minime repellentes ad ſe invicem attrahentur.

Eodem modo particulæ aëris elaſticæ repellentes, particulis aliis heterogeneis combinatæ, qualitatem ſuam elaſticam ſeu repulſivam amittere, & in mixtiones, compoſitiones ſolidas nonelaſticas abire, & poſtea tamen, ignis aut fermentationum actione extricatæ, priorem qualitatem elaſticam iterum recuperare poſſunt: probabile eſt hoc modo tantam aëris elaſticitatis copiam vaporibus animalibus in pulmone &c. deſtrui, vel aliis vaporibus ſulphureis, qui, aëre permixti, cum particulis ejus combinari iiſque adhærere poſſunt, elaſticitatem ejus, modo jam dicto, deſtruentes vel ſaltem multum imminuentes.

§ XXXIX. Sic etiam effectus quem exerit aër aduſtione ſeu vaporibus ſulphureis corruptus, in animalium reſpirationem, non pro cauſa vivificantis ſpiritus habet abſentiam, ſed aëris hujus ſummam ad veſiculas pulmonis diſtendendum inaptitudinem, quod efficit 1°. natura ejus inquinata vaporibuſque vim elaſticam enerventibus onerata, quibus 2°. Spaſmos partiales adducit 3°. Veſiculas ut aër purus fortiter haud extendit elaſticitatem vero aëris iis jam contenti magna ex parte deſtruit, ut videri poteſt, aërem mundum cum aëre inquinato miſcendo, quo multum illius abſorbetur 4°. Mixtione aëris hujus imprægnati cum exhalante vapore animali abſorbente pulmonis, non ſolum elaſticitas, mixtionibus particularum novis & combinationibus, ulterius multum infringi poteſt, (ut apparet, candelam vel animal in aërem iſtos vapores continentem, imponendo, ubi, quamvis per dimidium, ac in ſimili aëris puri temporis ſpatium non vivant, duplicem tamen deſtruunt elaſticitatis quantitatem) ſed etiam, combinationibus his, particulæ formari poſſunt craſſæ, quæ adhærendo, orificiaque parvula & ductus communicationis veſicularum exiliſſimos forte obſtruendo, motum pulmonum, ſicut & Sanguinis circulationem prorſus impediunt.

Quod aëris virtus vivificans in diſtenſione pulmonis alternativa tantummodo conſiſtat, evidentiſſimo apparet experimento doctiſſimi Hales, quo canem longo tempore vivum tenebat, pulmones aëre, ſulphuris ardentis vapore, impregnato, follis vi diſtendendo &c.

Hinc quando animal ſtagnatione Sanguinis ſyncope procubuit, ſibi relictum & vi thoracem dilatandi carens, perit; ſi vero, ſtimulo aliquo vel flatu, in veſiculas aër purus iterum admittatur, recreatur animal nullo conſequenti malo; ut experimentis in grotto del cani factis, hominibuſque vapore carbonum pene ſuffocatis, videtur.

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* Misprinting of *penetrat.*

§. XL. Oblatis jam aliquibus Sanguinis extra corpus phœnomenis, ad curſum nunc ejus vitalem, functioneſque ab illo pendentes, properandum eſt.

§. XLI. Sanguis ventriculo cordis ſiniſtro contentus, ſyſtole ejus, ad unciæ forte vulgo unius quantitatem, in Aortum aucto ſuo diametro cedentem, expellitur; hinc contractione hujus elaſtica expreſſus, qua data porta, ruit; quam primo in arteriis duabus coronariis, quo, ſyſtolis tempore, propter valvularum ad orificia eorum applicationem, fluere non potuiſſet, inveniens, per omnes minutas vaſculorum eorum ramificationes, propellitur, ubi nutritionis motuſque muſcularis incumbit uſui.

§. XLII. Materia, nutritionis propria haud facile determinanda eſt. Pro hac, maxima cum probabilitate, contendit lympha pellucida ſubtilis ſeroſa, quæ per omnia corporis puncta vel minima perfunditur, reficienda.

Poteſtne ſuccus eſſe nervoſus, qui partes vere ſolidas format? Cruor huic operi, in vaſis exiliſſimis, perficiendo, ineptus omnino deprehendetur. Omnia tamen fini huic, inſtrumentaliter ſaltem, inſervire poſſibile eſt; naturamque non una quadam liquorum animalium parte, ſed duabus vel pluribus uti, ſecundum deſideratorum ejus neceſſitatem, ſive ad defectus ejus ab attritione &c. ſupplendum ſive ad extendendum, prolongandum vel accretiones novas faciendum.

§. XLIII. Sed quâ ratione liquor hic arterioſus ad motum conducat muſcularem, difficilioris multo perquiſitionis eſt.

Multæ quidem doctorum hoc in campo ſunt conjecturæ, in quibus fere omnibus arterioſi liquoriſque nervoſi ponitur concurrentia, ab aliquibus forte nervoſi tantummodo neceſſitas.

Sed quomodo perficiantur rarefactiones hæ debitæ, inflationes, infarctiones & diſtentiones, quæ fibras muſculares in gradum talem abbreviare ſupponuntur, haud clare ſatis eluceſcit.

Et quidem omnes formæ principiaque mechanica quæ hunc in ſcopum afferri poſſunt, idonea minime videntur ut vim tantam, quanta Muſculorum in actione obſervatur, impetrarent.

Notum eſt, formarum mechanicarum applicatione, velocitatem in momentum mutari & vice verſa; ſemper vero (habita quidem, ad inſtrumentorum frictionem, ratione) emergit equivalens, nec ulla vis ex eo generatur nova.

Ubi tunc quærenda ſit velocitas, vel cauſæ hujus muſculummoventis momentum inveniendum eſt?

An Cordis impetus, maximo quidem calculo computatus par ullâ ratione? & ſi ſit, quid illud movet?

An ſimplex ſucci nervoſi influxio ſufficiens?

Tunc certe non ſine ſpecie veriſimilitudinis fuit, efferveſcentias rarefactiones exploſiones &c. hic effingere chymicas; hæ magnam quidem vim præbent; ſed eas contingentes ſupputare abſurdum foret, repugnante omni obſervatione.

Vim etiam magnam, funium madefactione, procreari videmus, ſed multa inter ejus & muſculi contrahentis phenomena, adeſt differentia:

Poteſtene, hunc in ſcopum, liquor tenuis, in texturam Muſculorum fibrilloſam, nervis infudi? qui, pro mentis arbitrio, in eo morari vel vaſculoſo quodam artificio ſubito removeri poteſt; certe conceptu difficile, nec ſatis ſufficiens æſtimandum. Hoc certe conſtat, quod fibræ non implicatæ, ut crines, humiditate minime contractæ ſunt ſed protractæ.

Si mihi meam parvi momenti opinionem, poſt tot ac tantorum virorum ſapientum conatus, proferre liceret, abſolute neceſſarium hic eſſe exiſtimarem, auxilium, cauſæ alicujus activæ potentis, ab omni lege Chymica Mechanica &c nobis adhuc cognita, omnino forſitan diverſæ, appellare.

Sed quid de cauſa prorſus incognita ſtatuendum?

In eam ſolummodo, ut ſignum, collineare, & cum aliis naturæ phænomenis comparando, conari, ut obſervationes aliquas analogice poſſibilitatem rei talis ſaltem monſtrantes, inferre poſſemus:

Nonne itaque credere poſſumus 1°. quod motus muſcularis ſimplici fibrarum componentium elaſticarum in ſemet ipſas contractione, perficiatur, ſine quidem fibrarum cavitatis, longe minus inflationis ſuppoſitione.

2°. Quod hoc perficiatur, quaſi magna, augmentatione illarum vis contractivæ elaſticæ, qua naturaliter, diſſecatæ &c contrahuntur.

3°. Quod hæc elaſtica ſeu contractiva, in actionem, influxu nervorum ſucci, cooperante etiam circulatione arterioſa, agatur cauſa.

Vis hæc contractiva certe, ex aliqua lege materiali ſecreta, nobis nondum ſatis perſpecta, pendet, aut virtute perficitur medii alicujus ſubtilis activi, corpora omnia facillime pervadentis, in ea vero, certis illorum conditionibus agentis.

Cujus rei exempla natura multa ſuppeditat ut ſupra allatis (§. XXXVIII.) videbitur: in magnetis porro & ferri phænomeno, ab attractione gravitatis in eo inter alia diſcrepante, quod magnetica valde limitata certis ſolummodo conditionibus, cum gravitas e contra, ſemper æqualiter in omni materiæ conditione peragatur; lege tamen materiali aut perficiatur, medii nempe auſpicio ſubtilis, vel immaterialiter immediate ab omnipotentis nutu pendet numinis.

Poteſtne ad motum muſcularem hoc applicari? ſed minime decet, non plus ultra fingere, ubicumque naturæ conſilium noſtrum exſuperet ingenium.

Stupendum Mediorum ſubtilium, in corpora modificatione peculiari prædita, effectum, docet tonitru phænomenon, enſem per intactam vaginam fundens, oſſaque, cute &c illæſa, contundens.

Radii Luminis, ſeu medium luminoſum a corpore albo, reflectuntur, mutato vero ſimpliciter colore in nigrum, maxima ex parte abſorbentur & diverſum, quatenus calefactionem ejus, edunt effectum.

Calore & frigore corpora expandi & contrahi cognoſcimus & hoc levitatis eorum ratione ſpecificæ; major etiam frigoris gradus duorum corporum mixtione produci poteſt, & hinc major contractio.

Quantum vero duo corpora, medium tale potens, applicatione ad ſe invicem modificare poſſint, Electricitatis phænomenis belle illuſtratur.

Parva quippe corporis electrici frictione per aliud corpus non electricum, vis attractiva &c excitatur &, omni diſtantia, per corpus non electricum, ſine ullo temporis intervallo ſenſibili, communicatur, & hoc non ſecundum corporis ſuperficiem, ſed, experimento ſtatuto, per internam ſolummodo, tenuiſſimi aurei V. G. ſtaminis, ſubſtantiam, æqua copia ac per corpus magnum liberaque ſuperficie præditum, tranſmittitur; & hæ vires, peculiari corporum electricorum & nonelectricorum applicatione, ita modificari & quaſi augeri poſſunt, ut minimi tantum filamenti acceſſu, percuſſionem, in animalibus ſolummodo perceptibilem, ea vero in quæ applicatur tueri ſatis valentem, edat corporibus.

Poteſtne animal machinæ electrificantis ſpecies exiſtimari? quatenus ex nonelectricis conſtituetur partibuſque electricis, in ſe invicem continuo applicatis, actis.

Poteſtne, ſanguinis globulorum, contra vaſorum capillarium latera, frictio, vim electricitati analogam excitare, & quæ, ſicut Electricitas, non, niſi applicatione quadam materiæ peculiari, manifeſtetur?

Poteſtne vis hæc, peculiari ſolidorum electricorum & fluidorum non electricorum applicatione, ita modificari ut validum in occaſione effectum, percuſſioni electricæ analogum, exercere poſſit, & quæ, mentis arbitrio, ſucci nempe nervorum applicatione, dirigatur?

Denique poteſtne vis hujus eſſe indoles ut fibras muſculares valide contrahere, quaſi aucta earum elaſticitate, efficiat. Ad circulationem vero ut redeamus.

§. XLIV. Sanguis, per arteriolas minores ſubdiviſionibus ſuis ſemper minuentes, tranſiens, in partes conſtituentes ſuas diverſas, quoad magnitudinem earum, ſeparatur.

§. XLV. Ita minutorum ope ductuum lateralium, pars ſeri ſubtiliſque aufertur lymphæ quæ vaſa circulans exiliſſima, nutritionis ibi fungetur munere & cujus lymphæ pars, exacta forte functione ſua, ex omni cordis ſuperficie externa, ſudoris vaporiſve forma exudatur, ad omnem pericardii cavitatem humectandum, lubrificandum; in oſcula deinde venoſa abſorbentia, recipienda.

§. XLVI. Lympha hæc nutricia non omnis, ſanguini, continuationibus arteriarum cappillarium venoſis, reducto, redditur; ſed propriis ipſius vaſibus, per varias glandulas lymphaticas tranſitura, vehitur & denique in ductum thoriacicum infunditur.

§. XLVII. Spoliatus ſic Lymphæ ſuæ parte ſanguis, ſeparata etiam ab eo alterneque reſorpta materia oleoſa ubique in ſubſtantia Celluloſa & particulas, quæ corpori ineptæ devenere, ſecum auferens, in venam cavam, ope venarum in truncos majores coeuntium injicitur.

§. XLVIII. Sic una ſanguinis arterioſi abſolvitur ſubcirculatio, quæ nutritionis circulatio appellari poteſt, eademque pene per totum corpus invenitur ſive in muſculis, membranis, oſſibuſve peragatur.

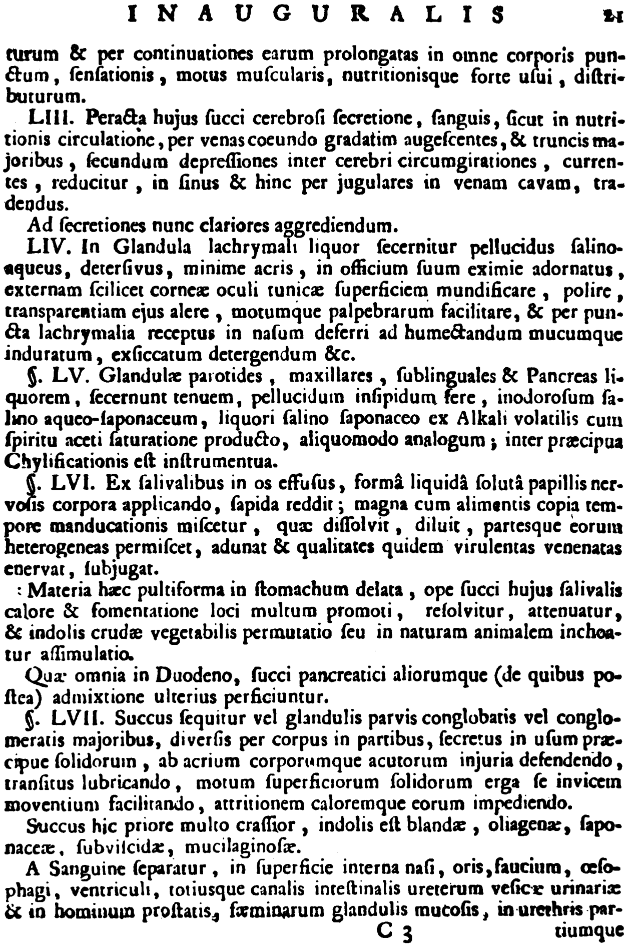
§. XLIX. Alia nunc ſanguinis arterioſi ſubcirculatio, ſecretionis nempe ſubeſt conſideranda.

Sanguis ex aorta, per diverſas arterias aortæ proles, in totum corpus, diſtributus, in glandulas ſecretionis organa propriis eorum affertur arteriis.

§. L. Quomodo diverſæ perficiantur ſecretiones huic brevi diſſerſertationi minime convenit, præſertim a peculiari cavitatum vaſorumque ſecernentium & abſorbentium pendet mechaniſmo; effectus ab diverſorum liquorum imbuatione quamvis in aquæ & olei mixtione ſuccedat, vix tamen, ad liquores ſibimet ipſis ſatis miſcibiles, applicari poteſt.

§. LI. Præcipua ſummæque neceſſitatis ſecretio, eodem vero tempore maxime obſcura, controverſa & minime quidem demonſtrabilis, ratione ſolummodo & analogia comprobata in cerebro perficitur.

§. LII. Sanguis per directa carotida miſſus, impetuoſitatem ſuam, inflectionibus ad cranii baſin anguloſis, coercitam multum habet; per ſubſtantiam deinceps cerebri & cerebelli corticalem quæ vaſorum exiliſſimorum congeries videretur, diſtributus, ibi, propter tenuiſſimam diviſionem, non ruber cinericio vero apparet colore, & hic ſeparari videtur ſuccus iſte vitalis, omni functioni, actioni, ſenſuique corporis, tam neceſſarius, de cujus vero natura prorſus ignoramus, &, præter fluiditatem ſubtilitatemque, aliam ejus æquam forte ideam in mente formare nequimus: hunc per albidam partis medullaris ſubſtantiam fiſtuloſam vehi imaginamur, ibique forſitan ulterius perfici, circumgiratas iſtas fibras tubuloſas varie unitas, ſeparatas, mixtas ſibique invicem, alternantes circula-



turum & per continuationes earum prolongatas in omne corporis punctum, ſenſationis, motus muſcularis, nutritionisque forte uſui, diſtributurum.

LIII. Peracta hujus ſucci cerebroſi ſecretione, ſanguis, ſicut in nutritionis circulatione, per venas coeundo gradatim augeſcentes, & truncis majoribus, ſecundum depreſſiones inter cerebri circumgirationes, currentes, reducitur, in ſinus & hinc per jugulares in venam cavam, tradendus.

Ad ſecretiones nunc clariores aggrediendum.

LIV. In Glandula lachrymali liquor ſecernitur pellucidus ſalino-aqueus, deterſivus, minime acris, in officium ſuum eximie adornatus, externam ſcilicet corneæ oculi tunicæ ſuperficiem mundificare, polire, transparentiam ejus alere, motumque palpebrarum facilitare, & per puncta lachrymalia receptus in naſum deferri ad humectandum mucumque induratum, exſiccatum detergendum &c.

§. LV. Glandulæ parotides, maxillares, ſublinguales & Pancreas liquorem, ſecernunt tenuem, pellucidum inſipidum fere, inodoroſum ſalino aqueo-ſaponaceum, liquori ſalino ſaponaceo ex Alkali volatilis cum ſpiritu aceti ſaturatione producto, aliquomodo analogum; inter præcipua Chylificationis eſt inſtrumentua.

§. LVI. Ex ſalivalibus in os effuſus, formâ liquidâ ſolutâ papillis nervoſis corpora applicando, ſapida reddit; magna cum alimentis copia tempore manducationis miſcetur, quæ diſſolvit, diluit, partesque eorum heterogeneas permiſcet, adunat & qualitates quidem virulentas venenatas enervat, ſubjugat.

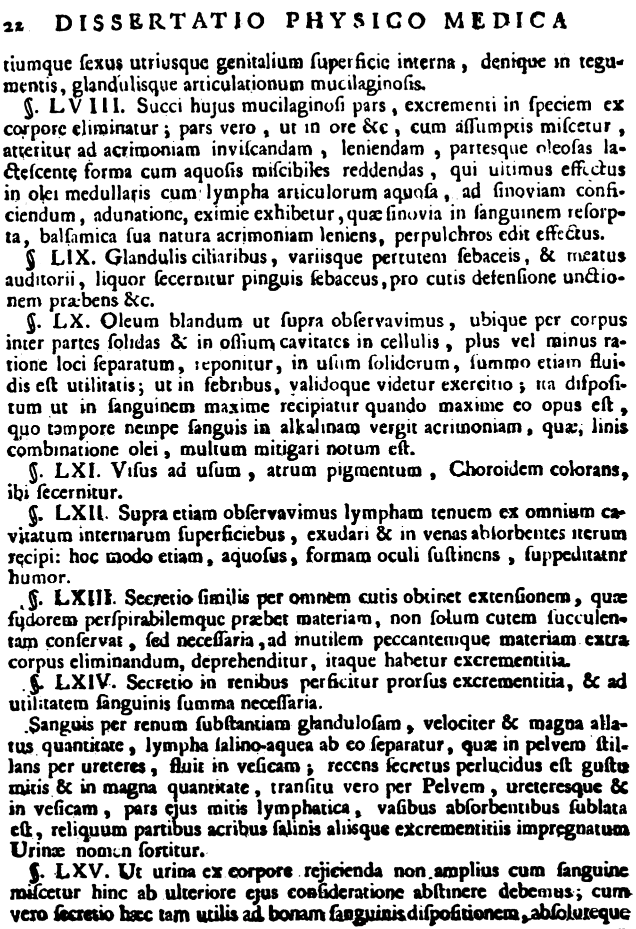
: Materia hæc pultiforma in ſtomachum delata, ope ſucci hujus ſalivalis calore & fomentatione loci multum promoti, reſolvitur, attenuatur, & indolis crudæ vegetabilis permutatio ſeu in naturam animalem inchoatur aſſimulatio.

Quæ omnia in Duodeno, ſucci pancreatici aliorumque (de quibus poſtea) admixtione ulterius perficiuntur.

§. LVII. Succus ſequitur vel glandulis parvis conglobatis vel conglomeratis majoribus, diverſis per corpus in partibus, ſecretus in uſum præcipue ſolidorum, ab acrium corporumque acutorum injuria defendendo, tranſitus lubricando, motum ſuperficiorum ſolidorum erga ſe invicem moventium facilitando, attritionem caloremque eorum impediendo.

Succus hic priore multo craſſior, indolis eſt blandæ, oliagenæ, ſaponaceæ, ſubviſcidæ, mucilaginoſæ.

A Sanguine ſeparatur, in ſuperficie interna naſi, oris, faucium, œſophagi, ventriculi, totiusque canalis inteſtinalis ureterum veſicæ urinariæ & in hominum proſtatis, fæminarum glandulis mucoſis, in urethris partiumque



tiumque ſexus utriusque genitalium ſuperficie interna, denique in tegumentis, glandulisque articulationum mucilaginoſis.

§. LVIII. Succi hujus mucilaginoſi pars, excrementi in ſpeciem ex corpore eliminatur; pars vero, ut in ore &c, cum aſſumptis miſcetur, atteritur ad acrimoniam inviſcandam, leniendam, partesque oleoſas lacteſcente forma cum aquoſis miſcibiles reddendas, qui ultimus effectus in olei medullaris cum lympha articulorum aquoſa, ad ſinoviam conficiendum, adunatione, eximie exhibetur, quæ ſinovia in ſanguinem reſorpta, balſamica ſua natura acrimoniam leniens, perpulchros edit effectus.

§ LIX. Glandulis ciliaribus, variisque pertutem ſebaceis, & meatus auditorii, liquor ſecernitur pinguis ſebaceus, pro cutis defenſione unctionem præbens &c.

§. LX. Oleum blandum ut ſupra obſervavimus, ubique per corpus inter partes ſolidas & in oſſium cavitates in cellulis, plus vel minus ratione loci ſeparatum, reponitur, in uſum ſolidorum, ſummo etiam fluidis eſt utilitatis; ut in febribus, validoque videtur exercitio; ita diſpoſitum ut in ſanguinem maxime recipiatur quando maxime eo opus eſt, quo tempore nempe ſanguis in alkalinam vergit acrimoniam, quæ; linis combinatione olei, multum mitigari notum eſt.

§. LXI. Viſus ad uſum, atrum pigmentum, Choroidem colorans, ibi ſecernitur.

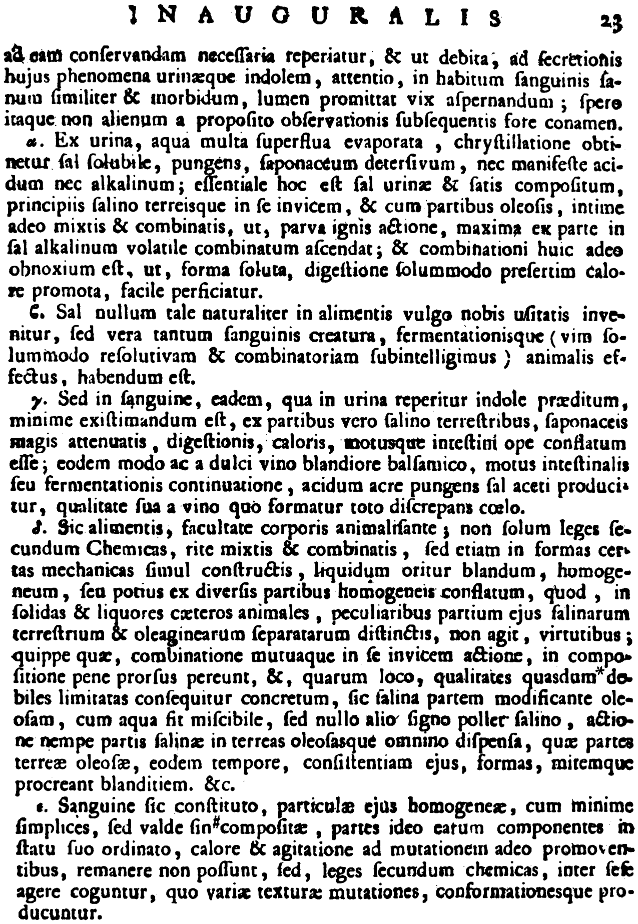
§. LXII. Supra etiam obſervavimus lympham tenuem ex omnium cavitatum internarum ſuperficiebus, exudari & in venas abſorbentes iterum recipi: hoc modo etiam, aquoſus, formam oculi ſuſtinens, ſuppeditatur humor.

§. LXIII. Secretio ſimilis per omnem cutis obtinet extenſionem, quæ ſudorem perſpirabilemque præbet materiam, non ſolum cutem ſucculentam conſervat, ſed neceſſaria, ad inutilem peccantemque materiam extra corpus eliminandum, deprehenditur, itaque habetur excrementitia.

§. LXIV. Secretio in renibus perficitur prorſus excrementitia, & ad utilitatem ſanguinis ſumma neceſſaria.

Sanguis per renum ſubſtantiam glanduloſam, velociter & magna allatus quantitate, lympha ſalino-aquea ab eo ſeparatur, quæ in pelvem ſtillans per ureteres, fluit in veſicam; recens ſecretus perlucidus eſt guſtu mitis & in magna quantitate, tranſitu vero per Pelvem, ureteresque & in veſicam, pars ejus mitis lymphatica, vaſibus abſorbentibus ſublata eſt, reliquum partibus acribus ſalinis aliisque excrementitiis impregnatum Urinæ nomen ſortitur.

§. LXV. Ut urina ex corpore rejicienda non amplius cum ſanguine miſcetur hinc ab ulteriore ejus conſideratione abſtinere debemus; cum vero ſecretio hæc tam utilis ad bonam ſanguinis diſpoſitionem, abſoluteque



ad eam conſervandam neceſſaria reperiatur, & ut debita, ad ſecretionis hujus phenomena urinæque indolem, attentio, in habitum ſanguinis ſanum ſimiliter & morbidum, lumen promittat vix aſpernandum; ſpero itaque non alienum a propoſito obſervationis ſubſequentis fore conamen.

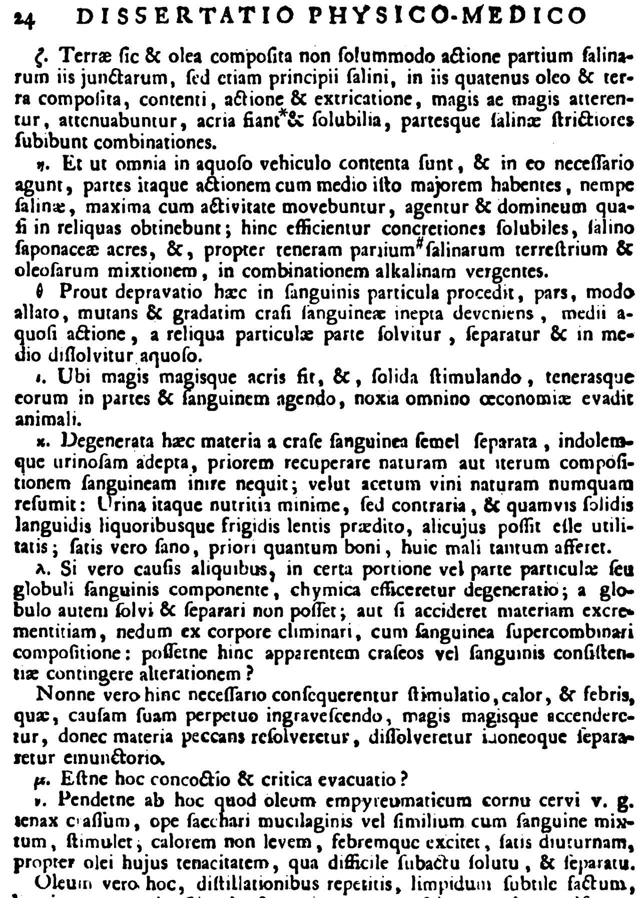
α. Ex urina, aqua multa ſuperflua evaporata, chryſtillatione obtinetur ſal ſolubile, pungens, ſaponaceum deterſivum, nec manifeſte acidum nec alkalinum; eſſentiale hoc eſt ſal urinæ & ſatis compoſitum, principiis ſalino terreisque in ſe invicem, & cum partibus oleoſis, intime adeo mixtis & combinatis, ut, parva ignis actione, maxima ex parte in ſal alkalinum volatile combinatum aſcendat; & combinationi huic adeo obnoxium eſt, ut, forma ſoluta, digeſtione ſolummodo preſertim calore promota, facile perficiatur.

ϐ. Sal nullum tale naturaliter in alimentis vulgo nobis uſitatis invenitur, ſed vera tantum ſanguinis creatura, fermentationisque (vim ſolummodo reſolutivam & combinatoriam ſubintelligimus) animalis effectus, habendum eſt.

γ. Sed in ſanguine, eadem, qua in urina reperitur indole præditum, minime exiſtimandum eſt, ex partibus vero ſalino terreſtribus, ſaponaceis magis attenuatis, digeſtionis, caloris, motusque inteſtini ope conflatum eſſe; eodem modo ac a dulci vino blandiore balſamico, motus inteſtinalis ſeu fermentationis continuatione, acidum acre pungens ſal aceti producitur, qualitate ſua a vino quo formatur toto diſcrepans cœlo.

δ. Sic alimentis, facultate corporis animaliſante; non ſolum leges ſecundum Chemicas, rite mixtis & combinatis, ſed etiam in formas certas mechanicas ſimul conſtructis, liquidum oritur blandum, homogeneum, ſeu potius ex diverſis partibus homogeneis conflatum, quod, in ſolidas & liquores cæteros animales, peculiaribus partium ejus ſalinarum terreſtrium & oleaginearum ſeparatarum diſtinctis, non agit, virtutibus; quippe quæ, combinatione mutuaque in ſe invicem actione, in compoſitione pene prorſus pereunt, &, quarum loco, qualitates quaſdum[*] debiles limitatas conſequitur concretum, ſic ſalina partem modificante oleoſam, cum aqua fit miſcibile, ſed nullo alio ſigno poller ſalino, actione nempe partis ſalinæ in terreas oleoſasque omnino diſpenſa, quæ partes terreæ oleoſæ, eodem tempore, conſiſtentiam ejus, formas, mitemque procreant blanditiem. &c.

ε. Sanguine ſic conſtituto, particulæ ejus homogeneæ, cum minime ſimplices, ſed valde ſin[#]compoſitæ, partes ideo earum componentes in ſtatu ſuo ordinato, calore & agitatione ad mutationem adeo promoventibus, remanere non poſſunt, ſed, leges ſecundum chemicas, inter ſeſe agere coguntur, quo variæ texturæ mutationes, conformationesque producuntur.



ζ. Terræ ſic & olea compoſita non ſolummodo actione partium ſalinarum iis junctarum, ſed etiam principii ſalini, in iis quatenus oleo & terra compoſita, contenti, actione & extricatione, magis ae magis atterentur, attenuabuntur, acria fiant[*] & ſolubilia, partesque ſalinæ ſtrictiores ſubibunt combinationes.

η. Et ut omnia in aquoſo vehiculo contenta ſunt, & in eo neceſſario agunt, partes itaque actionem cum medio iſto majorem habentes, nempe ſalinæ, maxima cum activitate movebuntur, agentur & domineum quaſi in reliquas obtinebunt; hinc efficientur concretiones ſolubiles, ſalino ſaponaceæ acres, &, propter teneram parjium[#] ſalinarum terreſtrium & oleoſarum mixtionem, in combinationem alkalinam vergentes.

θ Prout depravatio hæc in ſanguinis particula procedit, pars, modo allato, mutans & gradatim craſi ſanguineæ inepta deveniens, medii aquoſi actione, a reliqua particulæ parte ſolvitur, ſeparatur & in medio diſſolvitur aquoſo.

ι. Ubi magis magisque acris fit, &, ſolida ſtimulando, tenerasque eorum in partes & ſanguinem agendo, noxia omnino œconomiæ evadit animali.

κ. Degenerata hæc materia a craſe ſanguinea ſemel ſeparata, indolemque urinoſam adepta, priorem recuperare naturam aut iterum compoſitionem ſanguineam inire nequit; velut acetum vini naturam numquam reſumit: Urina itaque nutritia minime, ſed contraria, & quamvis ſolidis languidis liquoribusque frigidis lentis prædito, alicujus poſſit eſſe utilitatis; ſatis vero ſano, priori quantum boni, huic mali tantum afferet.

λ. Si vero cauſis aliquibus, in certa portione vel parte particulæ ſeu globuli ſanguinis componente, chymica efficeretur degeneratio; a globulo autem ſolvi & ſeparari non poſſet; aut ſi accideret materiam excrementitiam, nedum ex corpore climinari, cum ſanguinea ſupercombinari compoſitione: poſſetne hinc apparentem craſeos vel ſanguinis conſiſtentiæ contingere alterationem?

Nonne vero hinc neceſſario conſequerentur ſtimulatio, calor, & febris, quæ, cauſam ſuam perpetuo ingraveſcendo, magis magisque accenderetur, donec materia peccans reſolveretur, diſſolveretur idoneoque ſepararetur emunctorio.

μ. Eſtne hoc concoctio & critica evacuatio?

ν. Pendetne ab hoc quod oleum empyreumaticum cornu cervi v. g. tenax craſſum, ope ſacchari mucilaginis vel ſimilium cum ſanguine mixtum, ſtimulet, calorem non levem, febremque excitet, ſatis diuturnam, propter olei hujus tenacitatem, qua difficile ſubactu ſolutu, & ſeparatu.

Oleum vero hoc, diſtillationibus repetitis, limpidum ſubtile factum, brevi tantummodo ſtimulat &c, cito nempe reſolutum, & expulſum.

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[*] Misprinting of *quasdam*. [#] Misprinting of *sint*.

[*] Misprinting of *fient*.

@ Misprinting of LXVI.

§. LXVI. Secretio ſequitur conſideranda ultima, cæteris certe in dignitate & uſu haud cedens nobiliſſimo, utpote ſpeciei incumbens propagationi.

A Sanguine per arterias ſpermaticas in teſtes allato, in ſubſtantia eorum vaſculoſa mire convoluta humor lympidus ſecernitur, qui per vaſa deferentia in veſicularum ſeminalium cellulis reponitur.

Hic conſiſtentiæ ſi non qualitatis ſubit alterationem, abſorptis partibus magis aquoſis.

In ſucco hoc ſpermatico, blando, mucilaginoſo aqua tœpida diluta Microſcopii ope, multæ innatantes conſpiciuntur animalculæ.

§. LXVII. In circulatione glandularum annotandum eſt, quod, præter ſanguinem circulationem ſecretoriam ſubeuntem, alia portio per arteriam vel ramum ſibi proprium plerumque lata in glandulam, nutritioni, alterique forte inſerviat uſui.

§. LXVIII. Omnis aortæ ſanguis per totum corpus circulaturus, diſtributus, ut antea dictum eſt, pro nutritione, motu muſculari & ſecretione, per venas in ſe invicem coeuntes & ſic truncos efficientes majores truncis arterioſis reſpondentes, verſus cor reducitur, in cavam infundendus.

§. LXIX. Sanguis vero ex aorta deſcendente per Celiacam meſentericaſque miſſus arterias, duas, antequam cavam petat, tales jam deſcriptas percurrit ſubcirculationes; hoc modo.

Celiaca arteriiſque meſentericis, in ventriculum, omentum, Pancreas, inteſtinaque &c, pro nutritionis ſecretioniſque ſuccorum circulatione, diſtributis, ſanguis ab his in venas eorum proprias, venam portam unione ſua efformantes, colligitur, qua porta Hepar, eodem modo quo cæteræ ex propriis ſuis arteriis glandulæ, ſanguine ſuppeditatur.

Pars vero ſanguinis celiacæ in ſplenem miſſa, peculiarem ibi plane ſubit ſubcirculationem, hincque deinde in Hepar (hujus in uſum ſplenica hæc circulatio omnino deſtinata eſſe videtur, ad ſanguinem, nempe, arterioſum, impetu, qualitate forſan inidoneum, pro circulatione hepatica, morando, digerendo fluidioremque reddendo præparandum) per portam transfertur. Sanguis hic portæ venoſus, partibus oleoſis cum ſeroſitate abdominali conquaſſatis, ſulphureiſque ſaponaceis exaltatis, abſorptione refertus, per vaſa hepatis exilia, ſubſtantiamque ejus glanduloſam, arterioſæ in modum circulationis, motu vero lento, actione diaphragmatis muſculorumque abdominalium, præcipue promoto, transvehitur; & in venas ut antea augentes, in cavam infundendus iterum colligitur.

Bilis in minimis capillaribus ab eo ſecreta & in ductum Hepaticum collecta, in veſicum*fellis partem regurgitatur; pars major vero per ductum communem in inteſtinum fluit duodenum.

Liquor hic ſubviſcidus partibus ſalino-oleoſis ſaturatus, ſucco pancreatico dilutus, cum alimentis coctionem jam ſtomachi perpeſſis, intime mixtus, qualitate ſua ſumme ſaponacea, alimentorum cruditatem, ſubigente, texturam ſeu mixturam homogeneam multum efficiente, chylificationem quam maxime promovet.

Hæc omnia ulterius perficiuntur bile cyſtica, quæ, partibus magis aquoſis mora in veſica abſorptis, digeſtione calida, exaltatur efficacior fit, amara, colore obſcura, indolemque fere obtinet alkalicum; ſic admirabiliter concinnata, ut crudis in alimentis ſpeciem fermenti eſſet animalis, & egregia ſua ſtimulatione calida inteſtinorum motus, functiones pulcherrime excitaret.

§. LXX. Sanguis hepaticus; ſecunda hac ſubcirculatione peracta, in cavam perventus, omnis arterioſi ſanguinis in dextram cordis auriculam properaturi, reditum abſolvit.

Cum vero multis ſuis orbatur partibus, quæ in nutritione & ſecretione expenduntur & quarum aliæ ex corpore eliminantur aliæ vero chylificationi inſervientes, una cum chylo feruntur, cum ſanguine venoſo priusquam hic cor ingrediatur, immiſcendæ; Chylificatio itaque ſubeſt hic paucis obſervanda.

§. LXXI. Alimenta, ut antea dictum attrita, cum ſaliva mucoque mixta, digeſta, attenuata, iterumque cum ſucco pancreatico & bile utraque mixta, continuaque reſpirationis actione & motu periſtaltico conquaſſata, ſic dividuntur, attenuantur, miſcentur, & magna ex parte in ſuccum lateſcentem, chylum dictum, reducuntur: hic in orificia vaſorum lacteorum receptus, per eaque motu periſtaltico impulſus, lymphaque dilutus, & in chyli receptaculum infuſus, per ductum thoracicum, in venam fluit ſubclaviam ſiniſtram, gradatim ibi cum ſangnine mixtus, per venam cavam, cum eo deſcendit in auriculam & hinc in cordis ventriculum dextrum.

§. LXXII. Sanguis ſic, per totum corpus emiſſus, partibus ſuis variis ſpoliatus, iterum vero partem earum nactus majorem, & cum chylo nutritio ad defectus ſuos reparandum immixtus, in cor iterum redditur. Ut ſanguis vero hic ad eundem idoneus ſit curſum præſtandum, oportet, ut ſucci illi lymphatici chyloſique cum eo intime miſceantur, adunentur, modificentur, ad craſin ejus penitus reficiendam.

§. LXXIII. Sanguis itaque hic dextro cordis ventriculo contentus, ſyſtole ejus per arteriam pulmonalem, eodem, quo per aortam, modo, expulſus, in minutos pulmonum ramificatos tubos elaſticos capillares, valida ſatis vi ingeritur; hincque vaſis ſimilibus recipitur venoſis, per truncos eorum majores in auriculam cordis ſiniſtram, tradendus.

§. LXXIV. Ad curſum hunc ſanguinis celerrimum, per ſubſtantiam pulmonum vaſculoſam mirifice ramificatam, promovendum, actio inſpirationis & reſpirationis alternativa omnino eſt neceſſaria, quæ, influxum nunc in vaſa elaſtica diſtendentia liberum permittendo, liquorem nunc per venas reducentes valide exprimendo, liberam procreat circulationem, viſcida, moliculaſque majores conquaſſat, & ſanguinem chylumque plaſticum, tranſitu per gyrationes anguloſque minutorum tuborum cylindricorum, miſcet, comprimit, format quaſi & modificat.

§. LXXV. Quod aërem in pulmonibus cum ſanguine miſceatur aut ulla cum eo nuda habeatur communicatio, omni plane ratione caret & obſervatione.

Color floridus, hujus ſolum argumentum, mixtionis attritioniſque conquaſſatoriæ habetur effectus.

§. LXXVI. Alius hic in ſanguine contingens effectus eſt caloris generatio; quamvis & per cæteras corporis partes efficiatur hæc generatio, ut tamen ejus omnia hic, magno quidem gradu, inveniantur requiſita, effectum conſequenter neceſſario exerere debent proportionatum; nam cum in pulmone, ſubſtantiarum diverſarum mixtionem, conquaſſationem, attritionem, globulorumque ſanguinis & vaſorum laterum elaſticorum preſſionem frictionemque contingere videmus; neceſſario actio exinde magna, reactioque chymica ſequitur & mechanica; hinc calor & ejus conſequentia; quæ vero latiſſima ibi ſanguinis expanſione, mirificaque medii frigidioris applicatione, moderata ſunt perfecte, & belle prohibentur.

Diros quos in ſanguine calor medii hujus nimius producit effectus, experimento Illuſtriſſ. Boerhaave in canem inſtituto, videri poſſunt.

§. LXXVII. Sanguis circulatione refectus pulmonica, e venis pulmonum in auriculam cordis receptus ſiniſtram, hinc in ventriculum ejus (punctum quo incæpimus) diaſtolis tempore tranſiens, circulationem ſuam magnam perfectione coronat, ſtatimque curſum eundem variegatum mireque implicatum indefeſſo pede percuſſurus, proficiſcitur.

§. LXXVIII. Ut ſanguis non ſolum munerum ſuarum functione, ſed etiam natura ſua & conſtitutione continuo conſumitur, ſibi relictus, fato inevitabili cito periens; neceſſario ideo, idoneâ ad defectus ſuos reficiendum, ſubinde ſupplendus eſt, materiâ.

Cum vero vis corporis ſanguificandi, ſeu aſſimilatoria, operationis ſuæ ſubjectus reſpectu, eſt admodum limitata, hinc oportet, materiam hanc refecturam, non ſolum omnia ſanguinis principia, continere, ſed principia hæc certo modo miſceri, combinari, & debitis formis qualitatibuſque eſſe prædita, ut materia hæc, inſtrumentis animalibus & operationi aſſimilatoriæ, ſit obediens.

Succus ſic terræ crudus in ſanguinem noſtrum mutari nequit, quamvis vegetabilia ex eo formata ſcopo huic tam apta deveniant, & ſubſtantiæ animales ineptæ circulationi redditæ, vel putrefactionis ſtatu, ſanguinis conſtitutioni tam noxio; putrefactione vero penitus diſſolutæ, deſtructæ & in aërem terramque diſperſæ, iterum in vaſis vegetabilium miſcentur, in formas novas combinantur aptas, & ad compoſitionem liquorum animalium ſubeundum comparantur: Macrocoſmi circulationes pulcherrimæ ſic aguntur.

§. LXXIX. Alimentum generi humano forte utiliſſimum, & quod, ſtructura corporis, nobis deſtinatum fuiſſe videtur, fructus ſeu ſemen eſt farinaceum: hujus generis alimenta blanda ſunt viſcida emollientia, nullo ſale pungente nec oleo aromatico ſtimulante gaudentia, ſed ex mitioribus inſipidis ſaponaceo-viſcidis, terreoque ſalinis, cum partibus blandis oleoſis conjunctis, formata.

In aqua emolliuntur & intumeſcunt vix diſſolventia, niſi in aqua ebulliente ubi in mucilaginem viſcidam reſolvuntur, conſiſtentiam magnæ aquæ quantitati gelatinoſam, conciliantia.

Semina farinacea cruda, quamvis alimentum, homini robuſto exercitato, ſatis aptum poſſint præbere, inuſitato tamen magisve delicato viſcida nimis & refractoria inveniuntur, niſi debita fermentationis & coctionis encheriſe præparata.

Subſtantiarum fermentatione vegetabilium, partes ſalinæ latentes, &, inter partes earum oleoſo-terreſtres quaſi in clauſtro, reconditæ, operatione hac, extricatæ ſunt & aguntur; hoc modo partes craſſiores oleoſo-terreſtres rejiciuntur & fæcum forma præcipitantur, cæteræ ſupernatantes ſubtiliores fiunt, ſolubiliores, & multum ſuæ amittunt tenacitatis.

Semina itaque alimentaria, aliquem operationis fermentoſæ gradum, panis in præparatione, ſubeuntia, diviſibilia facilius, plaſtica & viribus Chylopoëticis ſubigi, bonumque in ſanguinem aſſimilari, aptiora evadunt.

Quer. an ſuccus alimentoſus in unam compoſitionem modificetur ſanguineam, ex qua cæteræ ſubinde, ſeu concretione ſeu diviſione, efficiantur omnes; vel an natura, ex Chylo ut Chao, varias particulas ejus diverſas, partibus ſanguinis reficiendis ſimillimas, & ad ſcopum ſuum maxime idoneas, eligat, applicet &c. Eſt ne hæc transmutatio aſſimilatoria? quæ non niſi exiſtente prius ſanguine hujuſve rudimentis, perfici poteſt.

Et augmentatio ſeu multiplicatio nonne perficitur, duarum particulæ ſanguinis diviſæ partium, in duas, prioris particulæ diviſæ ſimiles, particulas completas, accretione, perfectione? Hinc quo magis ſanguine bono abundat corpus, eo major alimenti in ſanguinem aſſimilatur co-

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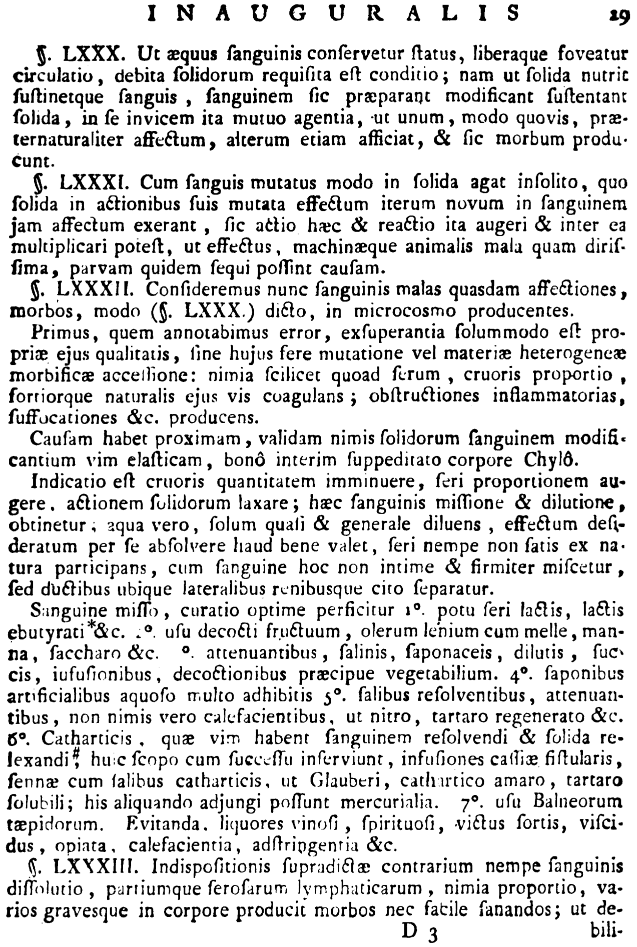
* Misprinting of *vesicam*.



§. LXXX. Ut æquus ſanguinis conſervetur ſtatus, liberaque foveatur circulatio, debita ſolidorum requiſita eſt conditio; nam ut ſolida nutrit ſuſtinetque ſanguis, ſanguinem ſic præparant modificant ſuſtentant ſolida, in ſe invicem ita mutuo agentia, ut unum, modo quovis, præternaturaliter affectum, alterum etiam afficiat, & ſic morbum producunt.

§. LXXXI. Cum ſanguis mutatus modo in ſolida agat inſolito, quo ſolida in actionibus ſuis mutata effectum iterum novum in ſanguinem jam affectum exerant, ſic actio hæc & reactio ita augeri & inter ea multiplicari poteſt, ut effectus, machinæque animalis mala quam diriſſima, parvam quidem ſequi poſſint cauſam.

§. LXXXII. Conſideremus nunc ſanguinis malas quasdam affectiones, morbos, modo (§. LXXX.) dicto, in microcoſmo producentes.

Primus, quem annotabimus error, exſuperantia ſolummodo eſt propriæ ejus qualitatis, ſine hujus fere mutatione vel materiæ heterogeneæ morbificæ acceſſione: nimia ſcilicet quoad ſerum, cruoris proportio, fortiorque naturalis ejus vis coagulans; obſtructiones inflammatorias, ſuffocationes &c. producens.

Cauſam habet proximam, validam nimis ſolidorum ſanguinem modificantium vim elaſticam, bonô interim ſuppeditato corpore Chylô.

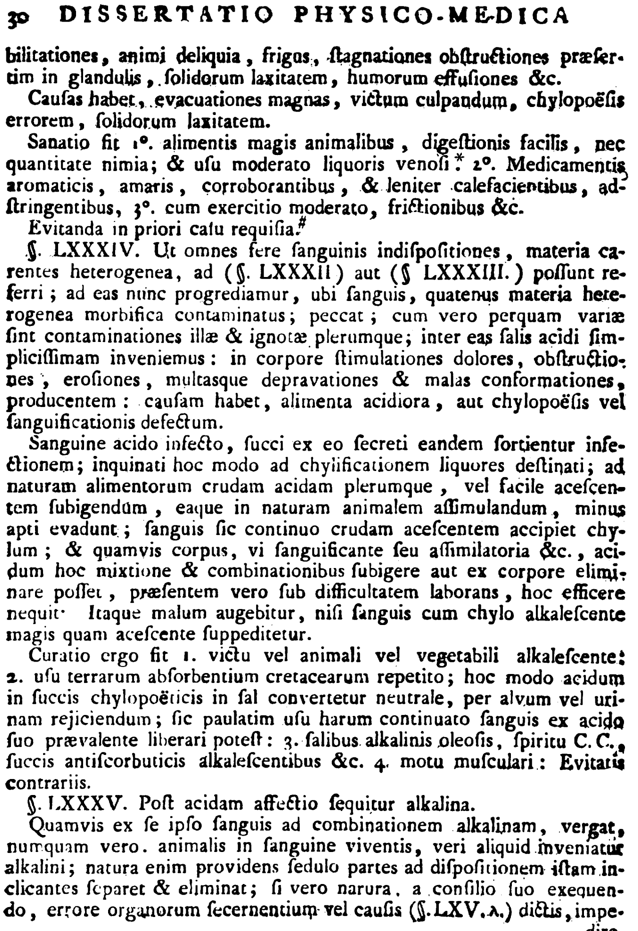
Indicatio eſt cruoris quantitatem imminuere, ſeri proportionem augere, actionem ſolidorum laxare; hæc ſanguinis miſſione & dilutione, obtinetur; aqua vero, ſolum quaſi & generale diluens, effectum deſideratum per ſe abſolvere haud bene valet, ſeri nempe non ſatis ex natura participans, cum ſanguine hoc non intime & firmiter miſcetur, ſed ductibus ubique lateralibus renibuſque cito ſeparatur.

Sanguine miſſo, curatio optime perficitur 1°. potu ſeri lactis, lactis ebutyrati[*]&c. 2°. uſu decocti fructuum, olerum lenium cum melle, manna, ſaccharo &c. °. attenuantibus, ſalinis, ſaponaceis, dilutis, ſuccis, infuſionibus, decoctionibus præcipue vegetabilium. 4°. ſaponibus artificialibus aquoſo multo adhibitis 5°. ſalibus reſolventibus, attenuantibus, non nimis vero calefacientibus, ut nitro, tartaro regenerato &c. 6°. Catharticis, quæ vim habent ſanguinem reſolvendi & ſolida relexandi[#]; huic ſcopo cum ſucceſſu inſerviunt, infuſiones caſſiæ fiſtularis, ſennæ cum ſalibus catharticis, ut Glauberi, cathartico amaro, tartaro ſolubili; his aliquando adjungi poſſunt mercurialia. 7°. uſu Balneorum tæpidorum. Evitanda. liquores vinoſi, ſpirituoſi, victus fortis, viſcidus, opiata, calefacientia, adſtringentia &c.

§. LXXXIII. Indiſpoſitionis ſupradictæ contrarium nempe ſanguinis diſſolutio, partiumque ſeroſarum lymphaticarum, nimia proportio, varios graveſque in corpore producit morbos nec facile ſanandos; ut de-

[*] Evidently a misprint, probably of *ebulliati*.

[#] Misprinting of *relaxand*.



bilitationes, animi deliquia, frigus, ſtagnationes obſtructiones præſertim in glandulis, ſolidorum laxitatem, humorum effuſiones &c.

Cauſas habet, evacuationes magnas, victum culpandum, chylopoëſis errorem, ſolidorum laxitatem.

Sanatio fit 1°. alimentis magis animalibus, digeſtionis facilis, nec quantitate nimia; & uſu moderato liquoris venoſi.[*] 2°. Medicamentis aromaticis, amaris, corroborantibus, & leniter calefacientibus, adſtringentibus, 3°. cum exercitio moderato, frictionibus &c.

Evitanda in priori caſu requiſia.[#]

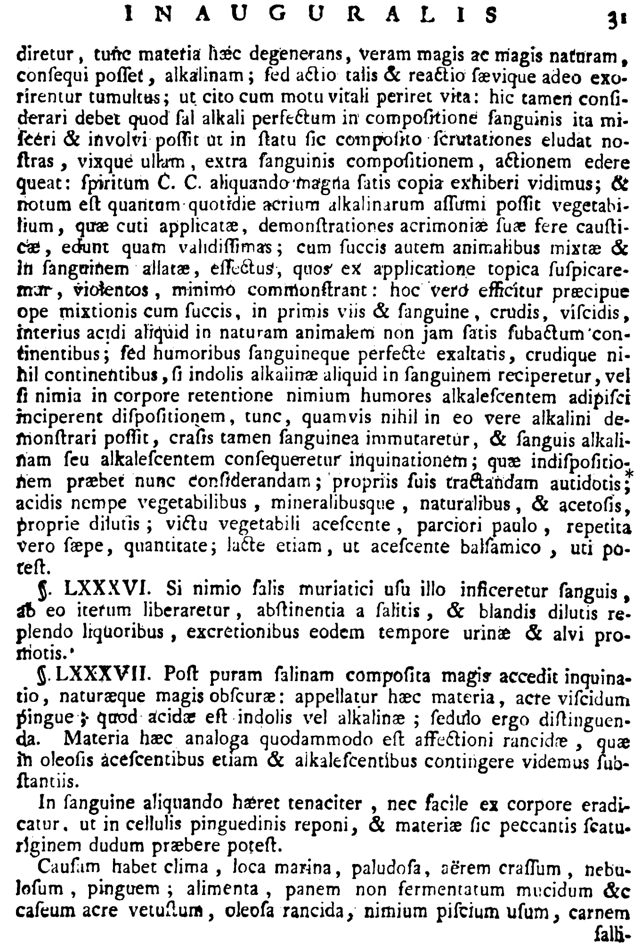
§. LXXXIV. Ut omnes fere ſanguinis indiſpoſitiones, materia carentes heterogenea, ad (§. LXXXII) aut (§ LXXXIII.) poſſunt referri; ad eas nunc progrediamur, ubi ſanguis, quatenus materia heterogenea morbifica contaminatus; peccat; cum vero perquam variæ ſint contaminationes illæ & ignotæ plerumque; inter eas ſalis acidi ſimpliciſſimam inveniemus: in corpore ſtimulationes dolores, obſtructiones, eroſiones, multaſque depravationes & malas conformationes, producentem: cauſam habet, alimenta acidiora, aut chylopoëſis vel ſanguificationis defectum.

Sanguine acido infecto, ſucci ex eo ſecreti eandem ſortientur infectionem; inquinati hoc modo ad chylificationem liquores deſtinati; ad naturam alimentorum crudam acidam plerumque, vel facile aceſcentem ſubigendum, eaque in naturam animalem aſſimulandum, minus apti evadunt; ſanguis ſic continuo crudam aceſcentem accipiet chylum; & quamvis corpus, vi ſanguificante ſeu aſſimilatoria &c., acidum hoc mixtione & combinationibus ſubigere aut ex corpore eliminare poſſet, præſentem vero ſub difficultatem laborans, hoc efficere nequit. Itaque malum augebitur, niſi ſanguis cum chylo alkaleſcente magis quam aceſcente ſuppeditetur.

Curatio ergo fit 1. victu vel animali vel vegetabili alkaleſcente: 2. uſu terrarum abſorbentium cretacearum repetito; hoc modo acidum in ſuccis chylopoëticis in ſal convertetur neutrale, per alvum vel urinam rejiciendum; ſic paulatim uſu harum continuato ſanguis ex acido ſuo prævalente liberari poteſt: 3. ſalibus alkalinis oleoſis, ſpiritu C. C., ſuccis antiſcorbuticis alkaleſcentibus &c. 4. motu muſculari: Evitatis contrariis.

§. LXXXV. Poſt acidam affectio ſequitur alkalina.

Quamvis ex ſe ipſo ſanguis ad combinationem alkalinam, vergat, numquam vero. animalis in ſanguine viventis, veri aliquid inveniatur alkalini; natura enim providens ſedulo partes ad diſpoſitionem iſtam inclicantes ſeparet & eliminat; ſi vero narura, a conſilio ſuo exequendo, errore organorum ſecernentium vel cauſis (§. LXV. λ.) dictis, impe-



diretur, tunc materia hæc degenerans, veram magis ac magis naturam, conſequi poſſet, alkalinam; ſed actio talis & reactio ſævique adeo exorirentur tumultus; ut cito cum motu vitali periret vita: hic tamen conſiderari debet quod ſal alkali perfectum in compoſitione ſanguinis ita miſceri & involvi poſſit ut in ſtatu ſic compoſito ſcrutationes eludat noſtras, vixque ullam, extra ſanguinis compoſitionem, actionem edere queat: ſpiritum C. C. aliquando magna ſatis copia exhiberi vidimus; & notum eſt quantum quotidie acrium alkalinarum aſſumi poſſit vegetabilium, quæ cuti applicatæ, demonſtrationes acrimoniæ ſuæ fere cauſticæ, edunt quam validiſſimas; cum ſuccis autem animalibus mixtæ & in ſanguinem allatæ, effectus, quos ex applicatione topica ſuſpicaremur, violentos, minimo commonſtrant: hoc vero efficitur præcipue ope mixtionis cum ſuccis, in primis viis & ſanguine, crudis, viſcidis, interius acidi aliquid in naturam animalem non jam ſatis ſubactum continentibus; ſed humoribus ſanguineque perfecte exaltatis, crudique nihil continentibus, ſi indolis alkalinæ aliquid in ſanguinem reciperetur, vel ſi nimia in corpore retentione nimium humores alkaleſcentem adipiſci inciperent diſpoſitionem, tunc, quamvis nihil in eo vere alkalini demonſtrari poſſit, craſis tamen ſanguinea immutaretur, & ſanguis alkalinam ſeu alkaleſcentem conſequeretur inquinationem; quæ indiſpoſitionem præbet nunc conſiderandam; propriis ſuis tractandam autidotis[*]; acidis nempe vegetabilibus, mineralibuſque, naturalibus, & acetoſis, proprie dilutis; victu vegetabili aceſcente, parciori paulo, repetita vero ſæpe, quantitate; lacte etiam, ut aceſcente balſamico, uti poteſt.

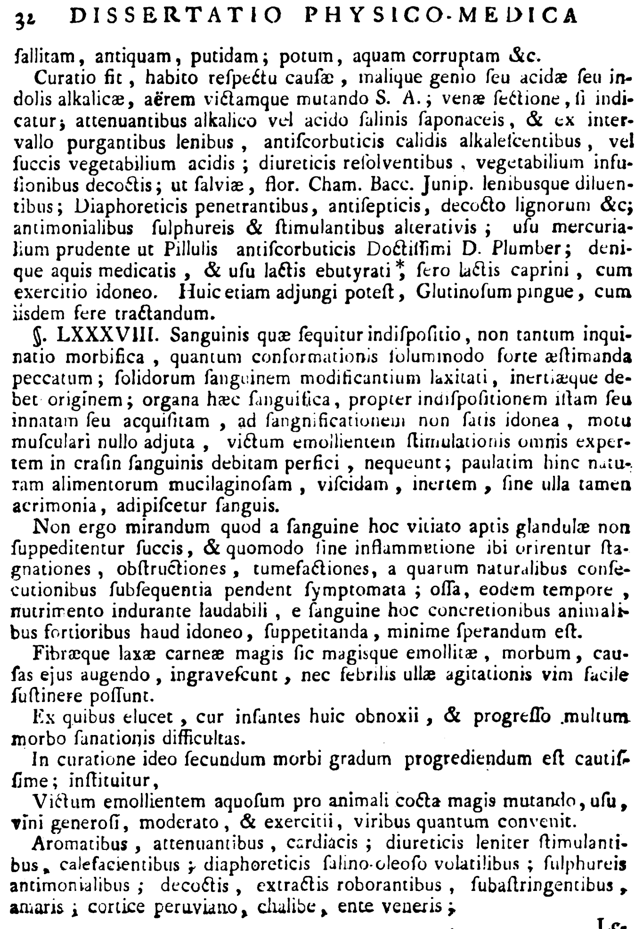
§. LXXXVI. Si nimio ſalis muriatici uſu illo inficeretur ſanguis, ab eo iterum liberaretur, abſtinentia a ſalitis, & blandis dilutis replendo liquoribus, excretionibus eodem tempore urinæ & alvi promotis.

§. LXXXVII. Poſt puram ſalinam compoſita magis accedit inquinatio, naturæque magis obſcuræ: appellatur hæc materia, acre viſcidum pingue; quod acidæ eſt indolis vel alkalinæ; ſedulo ergo diſtinguenda. Materia hæc analoga quodammodo eſt affectioni rancidæ, quæ in oleoſis aceſcentibus etiam & alkaleſcentibus contingere videmus ſubſtantiis.

In ſanguine aliquando hæret tenaciter, nec facile ex corpore eradicatur. ut in cellulis pinguedinis reponi, & materiæ ſic peccantis ſcaturiginem dudum præbere poteſt.

Cauſam habet clima, loca marina, paludoſa, aërem craſſum, nebuloſum, pinguem; alimenta, panem non fermentatum mucidum &c caſeum acre vetuſtum, oleoſa rancida, nimium piſcium uſum, carnem ſalli-

[*] Misprinting of *antidotis*.



ſallitam, antiquam, putidam; potum, aquam corruptam &c.

Curatio fit, habito reſpectu cauſæ, malique genio ſeu acidæ ſeu indolis alkalicæ, aërem victamque mutando S. A.; venæ ſectione, ſi indicatur; attenuantibus alkalico vel acido ſalinis ſaponaceis, & ex intervallo purgantibus lenibus, antiſcorbuticis calidis alkaleſcentibus, vel ſuccis vegetabilium acidis; diureticis reſolventibus, vegetabilium infuſionibus decoctis; ut ſalviæ, flor. Cham. Bacc. Junip. lenibuſque diluentibus; Diaphoreticis penetrantibus, antiſepticis, decocto lignorum &c; antimonialibus ſulphureis & ſtimulantibus alterativis; uſu mercurialium prudente ut Pillulis antiſcorbuticis Doctiſſimi D. Plumber; denique aquis medicatis, & uſu lactis ebutyrati[*], ſero lactis caprini, cum exercitio idoneo. Huic etiam adjungi poteſt, Glutinoſum pingue, cum iiſdem fere tractandum.

§. LXXXVIII. Sanguinis quæ ſequitur indiſpoſitio, non tantum inquinatio morbifica, quantum conformationis ſolummodo forte æſtimanda peccatum; ſolidorum ſanguinem modificantium laxitati, inertiæque debet originem; organa hæc ſanguifica, propter indiſpoſitionem iſtam ſeu innatam ſeu acquiſitam, ad ſangnificationem non ſatis idonea, motu muſculari nullo adjuta, victum emollientem ſtimulationis omnis expertem in craſin ſanguinis debitam perfici, nequeunt; paulatim hinc naturam alimentorum mucilaginoſam, viſcidam, inertem, ſine ulla tamen acrimonia, adipiſcetur ſanguis.

Non ergo mirandum quod a ſanguine hoc vitiato aptis glandulæ non ſuppeditentur ſuccis, & quomodo ſine inflammetione ibi orirentur ſtagnationes, obſtructiones, tumefactiones, a quarum naturalibus conſecutionibus ſubſequentia pendent ſymptomata; oſſa, eodem tempore, nutrimento indurante laudabili, e ſanguine hoc concretionibus animalibus fortioribus haud idoneo, ſuppetitanda, minime ſperandum eſt.

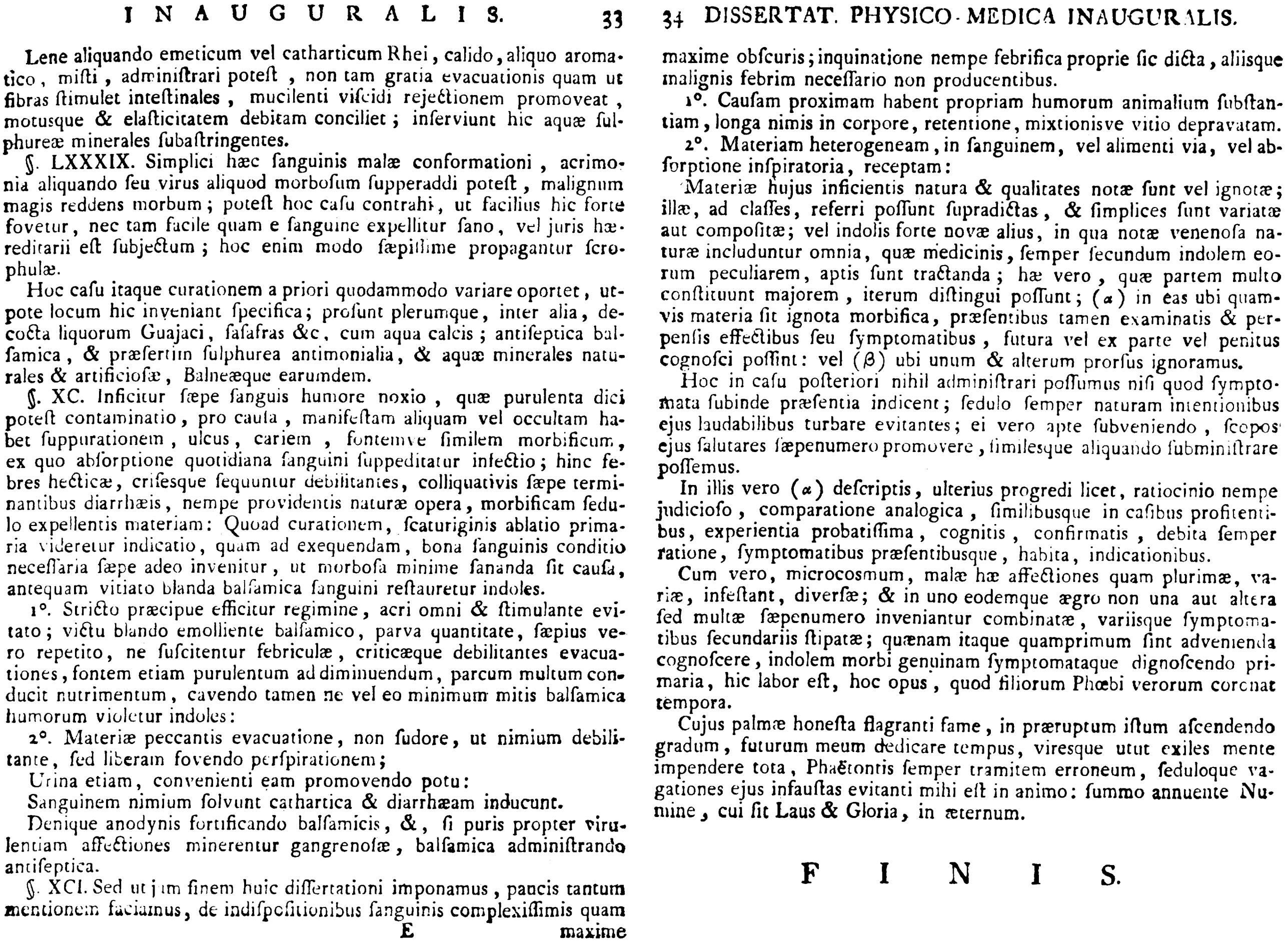
Fibræque laxæ carneæ magis ſic magiſque emollitæ, morbum, cauſas ejus augendo, ingraveſcunt, nec febrilis ullæ agitationis vim facile ſuſtinere poſſunt.

Ex quibus elucet, cur infantes huic obnoxii, & progreſſo multum morbo ſanationis difficultas.

In curatione ideo ſecundum morbi gradum progrediendum eſt cautiſſime; inſtituitur,

Victum emollientem aquoſum pro animali cocta magis mutando, uſu, vini generoſi, moderato, & exercitii, viribus quantum convenit.

Aromatibus, attenuantibus, cardiacis; diureticis leniter ſtimulantibus, calefacientibus; diaphoreticis ſalino-oleoſo volatilibus; ſulphureis antimonialibus; decoctis, extractis roborantibus, ſubaſtringentibus, amaris; cortice peruviano, chalibe, ente veneris;



Lene aliquando emeticum vel catharticum Rhei, calido, aliquo aromatico, miſti, adminiſtrari poteſt, non tam gratia evacuationis quam ut fibras ſtimulet inteſtinales, mucilenti viſcidi rejectionem promoveat, motusque & elaſticitatem debitam conciliet; inſerviunt hic aquæ ſulphureæ minerales ſubaſtringentes.

§. LXXXIX. Simplici hæc ſanguinis malæ conformationi, acrimonia aliquando ſeu virus aliquod morboſum ſupperaddi poteſt, malignum magis reddens morbum; poteſt hoc caſu contrahi, ut facilius hic forte fovetur, nec tam facile quam e ſanguine expellitur ſano, vel juris hæreditarii eſt ſubjectum; hoc enim modo ſæpiſſime propagantur ſcrophulæ.

Hoc caſu itaque curationem a priori quodammodo variare oportet, utpote locum hic inveniant ſpecifica; proſunt plerumque, inter alia, decocta liquorum Guajaci, ſaſafras &c, cum aqua calcis; antiſeptica balſamica, & præſertim ſulphurea antimonialia, & aquæ minerales naturales & artificioſæ, Balneæque earumdem.

§. XC. Inficitur ſæpe ſanguis humore noxio, quæ purulenta dici poteſt contaminatio, pro cauſa, manifeſtam aliquam vel occultam habet ſuppurationem, ulcus, cariem, fontemve ſimilem morbificum, ex quo abſorptione quotidiana ſanguini ſuppeditatur infectio; hinc febres hecticæ, criſesque ſequuntur debilitantes, colliquativis ſæpe terminantibus diarrhæis, nempe providentis naturæ opera, morbificam ſedulo expellentis materiam: Quoad curationem, ſcaturiginis ablatio primaria videretur indicatio, quam ad exequendam, bona ſanguinis conditio neceſſaria ſæpe adeo invenitur, ut morboſa minime ſananda ſit cauſa, antequam vitiato blanda balſamica ſanguini reſtauretur indoles.

1°. Stricto præcipue efficitur regimine, acri omni & ſtimulante evitato; victu blando emolliente balſamico, parva quantitate, ſæpius vero repetito, ne ſuſcitentur febriculæ, criticæque debilitantes evacuationes, fontem etiam purulentum ad diminuendum, parcum multum conducit nutrimentum, cavendo tamen ne vel eo minimum mitis balſamica humorum violetur indoles:

2°. Materiæ peccantis evacuatione, non ſudore, ut nimium debilitante, ſed liberam fovendo perſpirationem;

Urina etiam, convenienti eam promovendo potu:

Sanguinem nimium ſolvunt cathartica & diarrhæam inducunt.

Denique anodynis fortificando balſamicis, &, ſi puris propter virulentiam affectiones minerentur gangrenoſæ, balſamica adminiſtrando antiſeptica.

§. XCI. Sed ut jam finem huic diſſertationi imponamus, paucis tantum mentionem faciamus, de indiſpoſitionibus ſanguinis complexiſſimis quam

E maxime

maxime obſcuris; inquinatione nempe febrifica proprie ſic dicta, aliisque malignis febrim neceſſario non producentibus.

1°. Cauſam proximam habent propriam humorum animalium ſubſtantiam, longa nimis in corpore, retentione, mixtionisve vitio depravatam.

2°. Materiam heterogeneam, in ſanguinem, vel alimenti via, vel abſorptione inſpiratoria, receptam:

Materiæ hujus inficientis natura & qualitates notæ ſunt vel ignotæ; illæ, ad claſſes, referri poſſunt ſupradictas, & ſimplices ſunt variatæ aut compoſitæ; vel indolis forte novæ alius, in qua notæ venenoſa naturæ includuntur omnia, quæ medicinis, ſemper ſecundum indolem eorum peculiarem, aptis ſunt tractanda; hæ vero, quæ partem multo conſtituunt majorem, iterum diſtingui poſſunt; (α) in eas ubi quamvis materia ſit ignota morbifica, præſentibus tamen examinatis & perpenſis effectibus ſeu ſymptomatibus, futura vel ex parte vel penitus cognoſci poſſint: vel (β) ubi unum & alterum prorſus ignoramus.

Hoc in caſu poſteriori nihil adminiſtrari poſſumus niſi quod ſymptomata ſubinde præſentia indicent; ſedulo ſemper naturam intentionibus ejus laudabilibus turbare evitantes; ei vero apte ſubveniendo, ſcopos ejus ſalutares ſæpenumero promovere, ſimilesque aliquando ſubminiſtrare poſſemus.

In illis vero (α) deſcriptis, ulterius progredi licet, ratiocinio nempe judicioſo, comparatione analogica, ſimilibusque in caſibus profitentibus, experientia probatiſſima, cognitis, confirmatis, debita ſemper ratione, ſymptomatibus præſentibusque, habita, indicationibus.

Cum vero, microcosmum, malæ hæ affectiones quam plurimæ, variæ, infeſtant, diverſæ; & in uno eodemque ægro non una aut altera ſed multæ ſæpenumero inveniantur combinatæ, variisque ſymptomatibus ſecundariis ſtipatæ; quænam itaque quamprimum ſint advenienda cognoſcere, indolem morbi genuinam ſymptomataque dignoſcendo primaria, hic labor eſt, hoc opus, quod filiorum Phœbi verorum coronat tempora.

Cujus palmæ honeſta flagranti fame, in præruptum iſtum aſcendendo gradum, futurum meum dedicare tempus, viresque utut exiles mente impendere tota, Phaëtontis ſemper tramitem erroneum, ſeduloque vagationes ejus infauſtas evitanti mihi eſt in animo: ſummo annuente Numine, cui ſit Laus & Gloria, in æternum.

FINIS.

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